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**DEVELOPING THE MARINE
ENERGY SECTOR IN SCOTLAND:
A VIEW FROM THE ISLANDS**

NEAL MCMILLIN

**DEVELOPING THE MARINE ENERGY SECTOR IN SCOTLAND:
A VIEW FROM THE ISLANDS**

by
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A thesis submitted to the faculty of the University of Mississippi in partial fulfillment
of the requirements of the Sally McDonnell Barksdale Honors College.

Oxford 2014

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If you need an idea, you may be wise to take a hot shower. I conceived the genesis of this project during one of these. I realized that to apply for the Barksdale Award, I needed to focus on something which I had both experienced and cared about. From that thought, I realized that Scotland and water were my two topics to research.

For the project that sent me backpacking the Scottish countryside in the summer of 2013 and prepared my path to study marine affairs at the University of Washington starting in the autumn of 2014, I have many people to thank. First, I credit Dr. Jay Watson and Dr. Eric Weber for talking through my early ideas to focus on ocean renewable energy. I thank Dr. Debra Young for her encouragement for the Barksdale Award competition. Of course, thank you to the SMBHC staff, sponsors and family. I thank Dr. Ann Fisher-Wirth for pointing me to the environment studies path, Mr. Bill Rose for teaching me to be a journalist, and the Center for Southern Culture program which never limited my interests. To the many Scottish people who let me interview them, cooked friendly meals in hostels, and made my summer most memorable, thank you. I also thank my friends from my semester in Dundee, Scotland, who made the country such a wonderful place to me. I want to recognize my cousin Bill Sharman for his friendship and inspiration which shaped the vision of this project. Without a doubt, I would not have achieved this thesis without the high expectations and love from my family. Finally, I want to thank Dr. John Winkle and Dr. Andy Harper for their deep encouragement.

“Time and tide wait for no man.”

-Geoffrey Chaucer-

“Neither can the wave that has passed by be recalled, nor the hour which has passed return again.”

-Ovid-

THESIS ABSTRACT

In a world searching for environmentally-friendly alternative energy options, some people are looking to the ocean for answers. Through cutting-edge technology, engineers are devising ways to capture electricity from the power of the waves and tides. More than any other nation, Scotland is trying to develop a vibrant, domestic marine renewable energy hub. Instead of following the extraction-only model, Scotland seeks to achieve the entire ocean energy supply chain within the nation. An important first step towards this goal was the creation of the European Marine Energy Center (EMEC) in Orkney. The center hosts the leading test berths for tidal and wave energy devices. However, EMEC is only the beginning. The following thesis first analyzes the economic, political, and regional approaches to the Scottish marine energy sector. Then, the paper examines four Scottish island regions and their experience with ocean energy. After discussing the successes, failures, and barriers to date on Islay, the Outer Hebrides, Orkney, and Shetland, the project seeks to make key recommendations necessary for fulfilling the vision of a thriving Scottish marine energy industry.

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SCOTLAND



INTRODUCTION: A CALL FOR MARINE ENERGY

Mathis Wackernagel's scientific team pinpointed the 1980 as the year that the world began to consume natural resources more rapidly than the earth could restore them.¹ Over three decades later, the consequences from this practice of rampant ecological depletion now appear dire. In his manifesto *World on Edge*, Lester Brown, president of Earth Policy Institute, writes "Environmentally, the world is in overshoot mode." The statement emphasizes an accelerating reality. After surpassing the its equilibrium level of renewal, the earth is showing evidence of severe environmental stress. The ensuing problems needs to be ameliorated. A dramatic paradigm shift in global consumption is needed to bring the world back within its limits. The change must be pervasive. The change must be rapid to restore the planet to a sustainable balance. Brown suggests the world's response should be at a "scale and urgency similar" to the frenzy of U.S. mobilization during World War II -- but at the global level.² To help achieve such a decisive change, observers are looking to new spheres to replace the dwindling or damaging resources.

The end game is simply a livable planet. Many observers deem the earth's temperature cycle as a crucial target to stabilize. By now, the logic is familiar. A increasing level of carbon dioxide, just one of many greenhouse gases, traps more heat from the sun within the atmosphere which results in a surging average global

¹ Wackernagel, Mathis et al., "Tracking the Ecological Overshoot of the Human Economy," *Proceedings of the National Academy of Sciences*, vol. 99 no. 14 (9 July 2002), pp. 9,266-71.

² Brown, Lester R. *World On Edge: How to Prevent Environmental and Economic Collapse*. (New York City: W. W. Norton & Company 2011), pg. 16.

temperature. Alarming disasters are predicted to result from the warming climate such as glacier melt, sea-level rise, desertification, stronger storms, and crop failure. Only by reducing the concentration of carbon in the atmosphere will the world keep the earth's temperature from rising out of control. A dual approach is needed. While carbon needs to be returned from the atmosphere, our carbon emissions must be reduced. A strong response to the latter requirement would be to quickly revamp our energy system by changing to resources with lower carbon emissions. A rapid shift to renewable energy is the major strategy to reach this global goal.

The world needs carbon reduction, but still needs energy. The traditional fossil fuel energy sector cannot meet both requirements. Although they provide vast amounts of energy, coal, oil, and gas are initiating the cycle of climate change and environmental devastation by emitting carbon and other pollutants. Even without the pollution, the fossil fuel resource is finite. A change will eventually be necessary, but in the current state of the environment that change is needed today. Renewable energy is the dream remedy, the panacea to maintaining a functioning modern world. The former president of Eurosolar, Hermann Scheer was a strong early proponent of this promise of a renewables solution. In his 1999 acceptance speech for the Right Livelihood Award, also known as the Alternative Nobel Prize, Scheer stated "Renewable energies are inexhaustible. They do not destroy the environment... Their use facilitates solidarity with future generations... They secure the future of mankind."³ Scheer and many others' hope is that a robust system of renewable energy

³ Multon, Bernard. "Preface," *Marine Renewable Energy Handbook*. (London: John Wiley & Sons, Inc. 2012), pg. xvii.

will be able to provide for both the immediacy of our global energy demand and the long term imperative of climate stability.

Every day, as climate change becomes more apparent, global leaders are becoming more disconcerted. Many people within the U.K. government recognize that the ultimate cause of the nation's perceived growing insecurity is climate change. William Hague, the U.K.'s Foreign Secretary stated "You cannot have food, water or energy security without climate security."⁴ An island nation with declining traditional energy sources, the U.K. feels pressure from the changing world. Energy security is a major geopolitical concern for the country. In the Scotland and the U.K., the desire for alternative energy seems pressing for the nation's fossil fuel resources are expected to "diminish."⁵ Already, Britain has made the progression from exporting to importing oil. The country does not like the transition. Energy importing nations are both economically vulnerable and dependent on exporting nations. The national security argument strongly motivates the British government to encourage clean energy technology development. Renewable electricity helps solve both climate and energy security. With this in mind, the U.K. is embracing the renewables imperative. The U.K. sees both control and economic power returning to British shores in the alternative energy sector with the added benefit of environmental sustainability.

While some strategies produce heat, the majority of renewables produce electricity. Measuring electricity is not easily grasped by instinct. Before proceeding

⁴ Brown, 15.

⁵ *Renewable Energy & Western Isles: Creating a Sustainable Local Industry in the National Interest*. 2008 pg. 3.

further, I will clarify the measurements used for quantifying this energy. Electricity is calculated in three ways: watts, watt-hours, and homes. Watts refers to the amount of power at a specific instant. Watt-hours measure the amount of energy used up according to time and power intensity. Measuring watts is done by the metric scale. 1 watt (W) is the base. A kilowatt (kW) is 1,000 watts. A megawatt (MW) is 1,000 kilowatts. A gigawatt (GW) is 1,000 megawatts. Finally, a terawatt (TW) is 1,000 gigawatts.⁶ The abbreviation for hour, the standard time used, is simply a letter ‘h’ following the watt. To imagine electricity use in a more tangible manner, people use an estimated number of homes powered by the electricity. While the watt measurement is precise, the homes manner is relatively subjective. Homes are usually regionally specific in electric demand. No universal house electricity demand truly exists. In this paper, I will stress accuracy and rely on the watts method.

The previously described scale can be contextualized in two ways: capacity and generation. Electrical capacity refers to the maximum potential output of a device or generator. Electrical generation is the total amount of electricity produced over time. For example, a 10 MW capacity device can generate at optimal conditions 10 MWh of electricity in one hour. If the generator operated at half capacity for an hour, it would generate only 5 MWh.⁷ The tension between capacity and reality in many renewables has energy strategists looking to the deep blue sea for solutions.

⁶ “How Is Electricity Measured?” *Union of Concerned Scientists*. Last accessed May 27, 2014. http://www.ucsusa.org/clean_energy/our-energy-choices/how-is-electricity-measured.html

⁷ “What is the Difference Between Electricity Generation Capacity and Electricity Generation?” *U.S. Energy Information Administration*. Last accessed May 27, 2014. <http://www.eia.gov/tools/faqs/faq.cfm?id=101&t=3>

We live on the blue planet. More than 70% of the earth is covered by oceans. Could we capture energy from the offshore resource? Decades ago, the oil and gas industry answered in the affirmative. The oil companies drilled down beneath the water to extract the fossil fuels. Yet some observers realized that the actual power of the moving ocean was not something to ignore. The kinetic energy from the marine resource is renewable and, frankly, massive. Also called marine energy, blue energy, or wet energy, ocean power represents the largest sheer energy potential on the planet⁸ Legendary oceanographer Jacques Cousteau estimates that the total ocean power could equal 16,000 nuclear power plants. Even without accounting for the wave energy potential, tidal resources alone outstrip global wind resources by a ratio of nearly 1,000 to one.⁹ Also, the ocean resource is also quite close to a large electricity market which is important for resource viability since electricity loses energy as it travels. Approximately 44% of the world's population lives coastal areas within 150 kilometers of the sea.¹⁰ Powerful, renewable, sustainable, non-consumptive, near, free, and clean, marine energy is an enticing global treasure.

If capturing the incredible oceanic resource were easy, however, corporations would have done so long ago. Now undeterred by the challenge, companies are striving to develop surefire ways to convert the ocean's potential into kilowatts. If given enough time and money, the companies will succeed. The time requirement has

⁸ Gerdes, Louise. *Wave and Tidal Power*. (Farmington Hills, Michigan: Greenhaven Press 2010), pg. 7.

⁹ Benbouzid, Mohamaed, Jacques André Astolfi, Seddik Bacha, Jean Frédéric Charpentier, Mohamed Machmoum, Thierry Maitre and Daniel Roye. "Concepts, Modeling and Control of Tidal Turbines," *Marine Renewable Energy Handbook*. Ed. Bernard Multon. (London: John Wiley & Sons, Inc. 2012) pg. 222.

¹⁰ <http://coastalchallenges.com/2010/01/31/un-atlas-60-of-us-live-in-the-coastal-areas/>

discouraged some activists who extol urgency. Even the enthusiast Brown largely dismisses marine energy for his rapid “Plan B” to save the earth because of his desire for haste. Yet quickly developing more advanced renewable energy systems does not require overlooking the largest potential source of energy on the planet. Renewables needs an all hands on deck approach. As this paper finds, renewables are closely interrelated. While using the mature technologies now, develop new ones such as marine renewables so that the growth of clean energy can continue. No resource should be overlooked.

Engineers are developing two strategies for capturing the ocean energy source: tidal stream and wave energy technology. Aside from the climate benefits, the marine energy appears to be a lucrative opportunity. According to Adam Westwood, both the tidal and wave energy sectors are “high potential future markets.”¹¹ Marine energy company Clean Current Power Systems estimates the combined market for tidal and wave energy equipment could be \$200 billion. Again, the money is potentially present because the resource is immense. Wind energy leader Finavera estimates that combined the two strategies can potentially produce 2000 TWh/yr. To place the tetrawatts into context, the 2000 TWh/yr. would be the equivalent of 10% of the world’s yearly electricity consumption.¹²

French engineers made a foray into tidal energy well before other nations. On November 26, 1966, the La Rance Barrage became the first operating tidal energy

¹¹ Westwood, Adam. “*Marine Renewable Energy Report: Global Markets, Forecasts and Analysis 2005-2009.*” *Refocus: The International Renewable Energy Magazine*. (Oxford, U.K., Elsevier Advanced Technology 2005). pg. 3.

¹² Gerdes, 16.

power station. Across the Rance River estuary in Brittany Rance, engineers built a 24 turbine, 24 MW which produces each year about 600 GWh. After the development costs were overcome, the barrage produces electricity more cheaply than France's nuclear power plants. The tidal site has multiple uses. It attracts 70,000 visitors a year, serves as a highway, and provides a canal lock for boat passage. *Tres bien*. Well, not so fast. La Rance has some significant issues. The tidal device technology of the 1960s required a massive barrage to be built across an very ecologically sensitive estuary. Considerable, site-specific environmental changes resulted, primarily due to silting. In particular, many fish were affected. Sure, the ecosystem has since found a new equilibrium, but the estuary is a far cry from its original vibrancy. While La Rance omits minimal amounts of greenhouse gases, many consider the project to be too severe and expensive to justify the tradeoff between carbon reduction and localized environmental damage.¹³ As such, the world did not follow France's experiment. Nearly 50 years later, tidal barrages are still considered, most industry players are intrigued by the novel tidal stream technology which in theory could be cheaper and hopefully more environmentally benign.

The powerful changing tides are like the steady whistling wind of the underwater world. Tidal energy is powerful, densely concentrated and consistent. Powered by the moon, tidal energy is electricity captured from the direct consequence of the ebb and flow of the ocean's tides.¹⁴ To picture a tidal stream device array,

¹³ "La Rance Barrage," *Wyre Tidal Energy*. Last accessed May 27, 2014. <http://www.wyretidalenergy.com/tidal-barrage/la-rance-barrage>.

¹⁴ Westwood, 3.

imagine the turbines of a wind farm sunk beneath the ocean's surface. Each turbine is a stand alone structure but ideally gains electrical efficiency through connection with other turbines in an array arrangement.¹⁵ The most attractive commercial quality of tidal stream energy is predictability. Accurate forecasts of the tidal schedule can be made decades in advance. With this foresight advantage, tidal energy can be easily inserted into the demands of the electricity grid.¹⁶ Additionally, tidal energy has an immaterial seasonal fluctuation in electrical output.¹⁷ Therefore, the planning process is quite streamlined for providing adequate electricity. Also, tidal devices capture a densely concentrated energy which make the tidal resource ideal for large scale production. The compact structures are designed to be very efficient converters of the kinetic energy. The devices boast an 80% energy efficiency ratio for turning potential energy into actual electricity. To put this in perspective, a tidal turbine blade converts the same amount of energy as a windmill three times its diameter.¹⁸

Although observers are particularly optimistic with regards to tidal energy, significant barriers remain. Key obstacles for the tidal stream industry are device reliability, ease of maintenance, electricity output, array design, and expense.¹⁹ Furthermore, the extractable resource has limitations. Tidal devices are very location specific. First, the resource needs to be located near a densely concentrated tidal

¹⁵ Ramsay, Susan and Maf Smith. *On Stream: Creating Energy from Tidal Currents*. (Sustainable Development Commission Scotland 2008), pg. 7. Pamphlet.

¹⁶ Gerdes, 28.

¹⁷ Nerzic, Raymond and Jean-Pierre Mazé. "Marine Environment and Energy Resources," *Marine Renewable Energy Handbook*. Ed. Bernard Multon. (London: John Wiley & Sons, Inc. 2012) pg. 7.

¹⁸ Gerdes, 14.

¹⁹ Westwood, 113.

resource area. Strong resources are often present between individual islands or between an island and the mainland which means that space for the wide turbines are frequently limited by either geography or other sea users.

While the world's tidal resource "holds a certain fascination" because of its enormous energy potential, the technically extractable resource is much smaller than total resource.²⁰ While the 2012 Energy and Climate Change Select Committee estimated practical tidal energy capacity to be 116 TWh/yr., the 2011 Carbon Trust challenges that estimate as wildly optimistic. An independent organization, the Carbon Trust report estimates three scenarios for tidal: 30 TWh/yr. for an optimistic case, 20.6 TWh/yr. for a base level, and finally 10.3 TWh/yr. for a pessimistic scenario.²¹ The multi-national engineering firm Black and Vetch echoes the lower range of the estimates, stating that that "technically extractable tidal resource alone" could provide 3% of total U.K. electricity demand, or 12 TWh/yr.²² Still, tidal energy can expand to be a large contributor to the renewable energy mix even though the resource does have a ceiling. The strategy's limit is somewhere many gigawatts away.

Waves are the most visible form of ocean power. Again, the French recognized the energy first. French scientist Messrs. Girard titled his 1799 patent application as "*Pour divers moyen d'employer les vagues de la mer comme moteurs*"

²⁰ Brown, 130.

²¹ "Scottish Islands Renewables Project: Final Report," *Redpoint*. pg. 15. Last accessed May 27, 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199038/Scottish_Islands_Renewable_Project_Baringa_TNEI_FINAL_Report_Publication_version_14May2013_2_.pdf.

²² Bell, Michael and Jonathan Side. "Tidal Technologies: Key Issues Across Planning and Development for Environmental Regulators," *ICIT, Heriot Watt University*. Published March 2011. Last accessed May 27, 2014. pg. 3. <http://www.icit.hw.ac.uk/documents/SNIFFER-final-rep-20110203.pdf>

or “Various means of using ocean waves as driving forces ” are the title words for. Girard’s idea is perhaps the first written record of a plan to harness ocean wave power for energy purposes. Despite his foresight, interest in wave energy did not seriously arise until the 1973 oil embargo.²³ In 1974, Edinburgh University Professor Stephen Salter, now called the father of wave energy, developed a prototype named Salter’s Duck.²⁴ Interest since has waxed and waned based on global fuel prices.

Significant wave energy can be found almost anywhere between the 40 and 60 degree latitude marks because of the associated strong winds.²⁵ In an estimate from *Ten Technologies to Save the Planet*, a square meter of open North Atlantic ocean can contain as much as 70 kilowatts of electric potential, enough to electrify more than a hundred homes.²⁶ To capture this resource, wave energy converter transfers the wave’s rocking motion from kinetic energy into electricity.²⁷ Wave energy can be exploited through three types of strategies based on device location. Different prototypes have been tested in shoreline, nearshore, and offshore areas.²⁸

Of the blue energy strategies, wave energy presents the highest degree of engineering difficulty. For this reason, the sector is usually considered to be trailing the tidal industry. Some of the problems wave energy faces are resource

²³ Aubury, Judicaël, Hamid Ben Ahmed, Bernard Multon, Aurélien Babarit, and Alain Clément. “Wave Energy Converters,” *Marine Renewable Energy Handbook*. Ed. Bernard Multon. (London: John Wiley & Sons, Inc. 2012) pg. 324.

²⁴ Taylor, Jamie. “Evolution of Duck Full-Scale Engineering Design.” *Edinburgh Wave Power Group*. Last updated December 11, 2009. <http://www.mech.ed.ac.U.K./research/wavepower/>.

²⁵ Gerdes, 15.

²⁶ Goodall, Chris. *Ten Technologies to Save the Planet*. (London: Clays, Bungay, Suffolk 2008) pg. 90.

²⁷ Gerdes, 15.

²⁸ Westwood, 3.

intermittency, moving parts in saltwater, and harsh storm conditions. Often, suitable sites are a significant distance from shore which makes maintenance and design more arduous. The sheer force that makes wave energy such an attractive resource can be a prototype's demise.

If deployment for wave energy were “unconstrained” by other marine concerns, the Crown Estate estimates that total U.K. resource could equal 27 GW.²⁹ Yet like tidal, only a fraction of the wave energy resource can be captured. By floating on the surface, ideal sites for wave devices are often in the way of an existing use of the sea. Realistically, 10 - 13 GW, or 32 - 42 TWh/yr., of electricity can be captured from British waters by wave energy technology. Total deployment would significantly impact large areas of the British coastline. To visualize, a 10 - 13 GW force of devices would stretch nearly 500 kilometers long.³⁰

Despite the vision, tidal and wave resources have not been developed into a mature energy source. The marine environment present very rough conditions for machines. Individual full scale prototypes are undergoing testing, but a full array of commercial devices has not been established. Tidal stream is closer to commercialization. The state of the tidal industry is often compared to the emerging wind industry during the 1980s. Over 20 versions of tidal stream devices have been tested. While a general design for tidal devices has been acknowledged, an optimal

²⁹ “Scottish Islands Renewables Project: Final Report,” pg. 14. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199038/Scottish_Islands_Renewable_Project_Baringa_TNEI_FINAL_Report_Publication_version_14May2013_2_.pdf.

³⁰ Carbon Trust (2012). U.K. wave energy resource <https://www.carbontrust.com/media/202649/ctc816-uk-wave-energy-resource.pdf> iv

device has not yet emerged.³¹ For wave technology, two companies are considered to be the industry leaders, but the device design imagined is not similar. Commercial operation for wave power is in the planning process. Compared to wind power, the ocean energy strategies are a long way from the full commercialization level.

This paper seeks to outline the importance, vision, obstacles, successes and future plans of the marine renewable energy sector. With a strong focus on the economics of the industry and additional analysis of the associated environmental effects, the paper serves as a key perspective on the current and future impacts of tidal and wave renewable energy. To my best knowledge, the following thesis represents a unique study of the current state of the marine energy sector in Scotland. While a select few papers on marine renewable energy policy have been written, the typical focus is placed on the macro-economic potential of a fully developed industry, the future projections of the sector, or financing strategies for renewables. In contrast, this paper examines marine energy through a limited, place-specific context. With its Scottish focus, the thesis analyzes the leading nation in the ocean energy industry while controlling for country-specific variables. By looking at the industry's experience in Islay, the Outer Hebrides, the Orkney Islands, and the Shetland Islands, the paper can show tangible examples conditions that encourage or hinder marine energy development. At the same time, the thesis gives a national perspective to the state of the Scottish ocean energy sector. Finally, the paper reveals the very place-

³¹ Ramsay, 7.

specific nature of ocean renewable energy and the considerations associated with this understanding.

The most important aspect of my research is my first hand experience. Upon two occasions I have visited Scotland extensively. During the spring of 2012, I lived in Dundee, Scotland, and traveled to Edinburgh, Orkney, and Shetland. The experience prepared and inspired me to return to Scotland for the summer of 2013. For that trip, I backpacked through Edinburgh, Islay, the Outer Hebrides, Orkney, and Shetland, among other locations. Along with this firsthand experience, I conducted several interviews from scientists, policy makers, and locals. Beyond the onsite observations, I drew from government reports, technology statements, newspaper articles, and energy articles. As such, the project is almost entirely sourced from primary material.

The following thesis heavily relies on the framework, concerns, and rhetoric of an economics approach. This angle offers several advantages. By taking this perspective, the paper moves toward what appears to be the primary concern for marine energy to the Scottish Government, renewable energy companies, and the hosting communities: economic feasibility and profitability. The vision of a Scottish ocean energy hub relies on financial considerations. To my chagrin, however, the financial language and focus serves as more limited method for encountering the heart of the laudable pro-environmental intentions of the sector. Converting ecological considerations into monetary value is difficult and inexact at best and is beyond the scope of this thesis. Furthermore, blue energy is an emerging technology

with significant knowledge gaps on the total environmental impact of a commercialized sector. The theory behind ocean energy assumes the macro-impact of a lower carbon energy world exceeds the unknown micro-impact of the spatial disruption of the wave and tidal machines. At the present time, the verdict on this assumption is still to be determined. All the while, observers hope for development to proceed at a brisk pace, a notion which this paper affirms with some reserve. For now, the paper examines the critical economic climate surrounding Scottish ocean energy while recommending that further more overtly environmental scholarship be made as the experience with marine energy increases.

CHAPTER 1: SCOTLAND

Buffeted by fierce winds and crashing seas, the U.K. potentially has the largest per capita renewable energy resource in the world. If so, credit Scotland. The rugged northern nation has the resources needed to be the most renewable energy intensive region of the U.K. Blessed with the clean energy resources, Scotland has big plans for its renewables industry. Renewables engineering expert Bernard Multon notes that by 2050 many “local” regions should be able to achieve 100% of their electricity production from renewable energy sources.³² Scotland plans to go beyond the 100% target. Scotland aims to be a regional exporter of clean electricity through a robust ocean energy sector, extensive wind energy, and other renewables strategies.

With a historical affinity for water power, Britain seems a natural fit for marine energy development. Since the beginning of its industrial revolution, Britain has employed hydropower. At the turn of the nineteenth century, water energy powered about 75% of the cotton fiber mills.³³ Soon though, the industrial revolution in Britain literally picked up steam through coal-fired energy. Coal production provided for energy needs and drove development for decades. The British return to hydropower occurred in the Scottish Highlands from the 1940s to 1960s with the North of Scotland Hydro-Electric Board, a program inspired by the Tennessee Valley Authority in the U.S. The electricity and associated construction failed to lift up the

³² Multon, xviii.

³³ Simmons, Ian. *An Environmental History of Great Britain*. (Edinburgh: Edinburgh University Press 2001), pg. 140.

Highland economy by itself.³⁴ Just as the country had significant freshwater power resources, the U.K. has excellent ocean resources. Now, Scottish leaders look to the oceans as the new frontier for hydroelectricity.

The E.U. leads the world in taking proactive steps to combat climate change. E.U. legislation has helped prompt the U.K. to accelerate its renewable energy development. The European Council initiated a ‘20/20/20 by 2020’ platform to encourage member states to achieve the E.U.’s climate change goals. With 1990 as the baseline year, the initiative asks the nations to reduce total greenhouse gas emissions by 20%, total energy used by 20%, and produce from renewable sources 20% of total energy. The 20% targets were directed towards the U.K., but that has not stopped Scotland from taking its own initiative.³⁵ Of the three parts of the ‘20/20/20’, Scotland has focused keenly on the production aspect.

Led by Scottish National Party leaderships, Scotland has tried to differentiate itself from the rest of the U.K. by setting non-legally binding renewable energy targets that exceed the E.U. requirements for Britain. Under First Minister Alex Salmond, Scotland has repeatedly raised its renewable energy goals. As of 2013, the E.U. required the U.K. to produce 15% of its total energy through renewable sources by 2020. In response, the U.K. adopted a 30% renewable energy goal by 2020. With its current output of 25% renewable energy, Scotland moved its personal goal from

³⁴ Simmons, 224.

³⁵ Arbon, Ian. “Scotland’s Struggle,” *Holyrood Magazine*. Published June 14, 2010. Last accessed May 27, 2014. pg. 8 http://www.imeche.org/docs/default-source/learning-and-professional-development-documents/Holyrood_Magazine_article_-_published.pdf?sfvrsn=0.

50% to 80% to a bold 100% by 2020.³⁶ While traditional hydropower and offshore wind energy are expected to carry the bulk of the Scottish renewable production by 2020, tidal and wave energy are expected to become a key part in the renewables mix when the technology develops beyond the goal date. While the total U.K. tidal and wave capacity in early 2010 was just 2.4 MW, David Kidney, the U.K. Energy and Climate Change Minister, predicted that tidal and wave energy capacity could reach 2 GW by 2020.³⁷ Though planners are wise to rely on other renewables for the bulk of the Scottish production by 2020, marine energy should not be dismissed, even at the early date.

Many people wish that tidal and wave energy development could be accomplished quickly, most observers do not expect the technology to mature to the commercial level soon. Few expect rampant commercialization of ocean energy by 2020. At the same time, the capacity level of Scottish marine renewables by 2020 will be a harbinger for the industry's future status. If blue energy still lags too far behind other renewables, the industry may again shift focus away from the potential resource. The disconnect between hopes and expectations, attention and urgency stymies marine energy efforts. Tidal and wave may not be the quick, easy solution to a pressing target, but the ocean energy should be demanded to rise up for the long term development of a robust renewable energy mix.

³⁶ Bell, pg. 1. <http://www.icit.hw.ac.uk/documents/SNIFFER-final-rep-20110203.pdf>.

³⁷ Backwell, Ben. "The UK's Wave and Tidal Generation Capacity Could Reach 2 GW by 2020, Energy and Climate Change Minister David Kidney Says," *Recharge*. Published March 4, 2010. Last accessed May 27, 2014. http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

Since Scotland first embraced the potential for marine energy, the vision has shifted. Upon the launch of the Saltire Prize in 2008, Scottish First Minister Alex Salmond famously declared that the Pentland Firth tidal resource was the “Saudi Arabia” of marine energy.³⁸ At that time, Scotland viewed the benefits of tidal and wave energy as primarily through energy production. The idea was that Scotland had a very strong resource, so energy companies need to pay attention and devise a way to capture the power. Since then, tidal and wave energies have made considerable gains towards technological maturity. Now, Salmond has a new metaphor. In a speech in California, he compared Scotland’s renewable energy cluster potential to the state’s computer technology industry. Salmon said “Scotland is becoming the Silicon Valley of marine energy worldwide... As high tech industries concentrated in Silicon Valley and transformed the economic landscape of Northern California so marine energy will do for Scotland.”³⁹ By imagining a Silicon Valley instead of a Saudi Arabia, Scottish leaders raised the stakes. No longer does Scotland merely want to host marine energy devices. The shift changes the emphasis from profiting through mere resource richness to gaining prosperity through a total service marine energy hub. The change in paradigm could bring great financial rewards to the country. If Scotland misfires, the loss will be lamented more intensely.

The marine energy hub goal recognizes the impact of energy and jobs in tandem. Job creation in Scotland is, of course, a “top priority” for the Scottish

³⁸ Murray, James. “Scotland Aiming to Become ‘Saudi Arabia Renewable Marine Energy’,” *BusinessGreen*. Published December 3, 2008. Last accessed May 27, 2014. <http://www.businessgreen.com/bg/news/1804187/scotland-aiming-saudi-arabia-renewable-marine-energy>.

³⁹ “Scotland the ‘Silicon Valley’ of Marine Energy,” *Scottish National Party*. Last accessed May 27, 2014. <https://www.snp.org/blog/post/2012/jun/scotland-silicon-valley-marine-energy>.

National Party, the current party in power in Edinburgh. The Scottish Government looks to the private sector for the job growth. While the SNP outlines a few small business protections and some employment help for youth, the party's only platform for significant job creation is "growing the green economy."⁴⁰ The party hopes to achieve brisk growth in the sector by directing private investment into renewable energy, particularly through the National Renewables Infrastructure Fund (NRIF).

Though the largest focus for renewables in Scotland is on both onshore and offshore wind, the tidal and wave energy sectors is an attractive futures market that is very important politically. The ocean energy sector is of critical cross-party importance. The Scottish marine energy sector is a matter of "urgency and high government priority" for reasons of global climate change and energy security.⁴¹ Yet for the near future, expectations are low for marine energy's contribution to the energy sector. For the 2020, experts posit a modest estimate of 0.5 GW - 2.0 GW of electricity derived from tidal and wave and connected to the U.K. grid.⁴² Thus, the Scottish Government must approach the marine sector with a long term view while also giving it immediate attention. In the 2012 Report on the Achievability of Scottish Renewable Energy Targets, the Scottish parliamentary committee determined marine

⁴⁰ "Economy and Jobs," *Scottish National Party*. Last accessed May 27, 2014. <https://www.snp.org/vision/wealthier-scotland/economy-jobs>.

⁴¹ Bell, pg. i. <http://www.icit.hw.ac.uk/documents/SNIFFER-final-rep-20110203.pdf>

⁴² Bell, pg. 3. <http://www.icit.hw.ac.uk/documents/SNIFFER-final-rep-20110203.pdf>

energy was a “special case” worth helping to establish Scotland as the leader in the field.⁴³

In its efforts to show commitment to the marine sector, Scotland may have outmaneuvered itself. The raised expectations for the renewable energy targets were motivated by political points, optimism, recognition of the abundant resources, a desire to signal confidence to industry, perhaps a beat-the-Brits mentality, an attempt to gain the E.U.’s favor, or an excessive faith in sheer willpower. Regardless, the set targets failed to adhere to the pragmatic engineering criteria of the S.M.A.R.T. concept. The targets lack a “specific” planned path to success, “measurable” progression stages for the project, “achievable” in light of current technology, a “realistic” chance of completion, and logical “time-bound” deadlines. Hope and optimism fail to compensate for the absence of S.M.A.R.T. principles.

So while the current Scottish government continues to “very bullish” about the nation’s ability to meet the ever-rising goals, engineers are skeptical about Scotland’s near future capability. Scottish renewable energy expert Ian Arbon says “We must stop congratulating ourselves for setting targets which have no chance of being achieved; we need to stop the prevarication over our 2020 commitments.”⁴⁴ Arbon is correct. Scotland’s congratulatory attitude towards renewable energy production undermines the depth of the commitment needed to actually achieve the goals. The renewables hubris suggests that no greater effort is needed.

⁴³ The Scottish Parliament. Economy, Energy and Tourism Committee. 7th report, 2012 (Session 4). “Report on the Achievability of the Scottish Government’s Renewable Energy Targets. Scottish Parliament Paper 220. Published on November 23, 2012. Last accessed on May 27, 2014. pg. 29. <http://www.scottish.parliament.uk/parliamentarybusiness/CurrentCommittees/57013.aspx>.

⁴⁴ Arbon, 9.

Furthermore, many engineering minds recognize a pervasive slight of hand (intentional or not) between the terms electricity and energy. The Institute of Mechanical Engineers (IME) report “Scottish Energy 2020?” further questions the goal-setting enthusiasm based on the actual definitions of these words. The primary rift between the Scottish energy aspirations and the IME report is the definition of renewable energy. Energy and electricity are routinely used interchangeably in government statements and in the media. The terms are not synonyms. Energy is more expansive than electricity. By referring to the two as if the meaning were equivocal, the importance of electricity is inflated. Worldwide, electricity composes only about 17% of final energy consumption.⁴⁵ In Scotland, electricity represents the smallest third of the national energy requirements. Energy for heating and for transportation easily outweigh energy needed for electricity.⁴⁶ Until all heating and transportation are powered by electricity, the distinction between energy and electricity must be made. Scotland taking first steps in the electrification direction. For example, at least 218 miles of electrified railroad track have recently been constructed, with more lines in the planning stages.⁴⁷ As important as it is to develop technologies to use electricity, developers must still find ways to produce more clean electricity. This production goal occupies the overwhelming renewable energy

⁴⁵ Multon, xvii.

⁴⁶ “Scottish Energy 2020?” *Institute of Mechanical Engineers*. Published November 2011. Last accessed May 27, 2014. pg. 2. http://www.imeche.org/docs/default-source/events/IMechE_Scottish_Energy_Report.pdf?sfvrsn=0.

⁴⁷ “The Environment,” *Scottish National Party*. Last accessed May 27, 2014. <https://www.snp.org/progress/environment>.

attention in Scotland. The confidence plus the narrower total focus suggests that all-in-all Scottish green energy accomplishments may be more limited than advertised.

The Scottish Government contests the hard-eyed naysayer viewpoint. “We know there is doubt and skepticism about our 100% renewables target, and the financial and engineering challenges required to meet it” admits Scottish Energy Minister Fergus Ewing “but we will meet these challenges... We know our target is technically achievable.”⁴⁸ Ewing bases his confidence off the recent Electricity Generation Policy Statement (EGPS). The EGPS consolidated research studies and determines that four goals can be achieved: electricity supply security, lower cost, no carbon electricity generation emissions by 2030, and large economic benefit for Scotland. The report is quite optimistic.⁴⁹ The hopefulness is further encouraged by the government tendency to rely on energy company views on the state of the technology. Typically, the renewables companies overestimate their capability and underestimate delays. After all, the companies are trying to woo government support for their technology. By trying to pick just winners instead of endorsing the entire marine renewables industry, Scotland entices more propitious estimates. Scotland would do well to listen to additional sources that have a smaller personal stake in the success of the blue energy industry.

While focusing on the production aspect of renewable energy, the Scottish Government also notes that the emissions side of the ‘20/20/20’ equation is under

⁴⁸ “Scottish Electricity Generation,” *The Scottish Government*. Published March 5, 2012. Last accessed on May 27, 2014. <http://www.scotland.gov.uk/News/Releases/2012/03/Electricity-05032012>.

⁴⁹ “Electricity Generation Policy Statement,” *The Scottish Government*. Last accessed on May 27, 2014. <http://www.scotland.gov.uk/Resource/0038/00389294.pdf>.

consideration. Scotland is not a nation to fail to accept good press. Scotland set an E.U. record in decreased total emissions. In 2011, emissions dropped by 9.9% from 2009, the previously measured year. However, the record reveals less progress than a first glance may suggest. The emissions reduction record was based purely on percentages which are skewed because of the report's change in baseline data. Thus, the percentages were inflated. In quantity terms, the 2011 carbon reduction failed to meet Scotland's target goal. The baseline change means Scotland's ideal reduction total actually increased to 44%.⁵⁰ The higher standards present all the more reason for blue energy development.

A significant problem with the E.U.'s focus on emissions reduction is that nuclear waste is considered greenhouse gas free. Scotland rejects the harmlessness view of nuclear energy. The two remaining nuclear power plants are expected to be phased out when the lease is finished in the next decade. The SNP vows point-blank that "there will be no new nuclear power stations in Scotland."⁵¹ The nationalist party, currently in the majority, vehemently opposes all things nuclear. Nuclear weapons, power stations, and dumps are not a part of its vision for Scottish. On the other hand, England and some of the E.U. continue to rely on nuclear, even valuing it as a non-carbon polluting source. Some SNP representatives do little to hide their scorn for the British nuclear fixation. Caithness, Sutherland, and Ross MSP Rob Gibson links the perceived "U.K. Government's dithering attitude" towards Scottish renewable energy

⁵⁰ "Scotland Leads Europe on Climate Change Stats," *The Scottish Government*. Published June 7, 2013. Last accessed May 27, 2014. <http://www.scotland.gov.uk/News/Releases/2013/06/climatechangestats07062013>.

⁵¹ "The Environment," <https://www.snp.org/progress/environment>.

concerns as part of the British loyalty to the nuclear energy lobby. With the vast potential of British renewable resource, Gibson is exasperated by the reliance on nuclear power. He goes on to say “The fact that the U.K. Government continues to direct its support at nuclear power is bewildering.”⁵² Scotland is determined to produce more than enough electrical energy without the help of the toxic resource. For this qualification, Scotland should be both applauded and emulated.

Remaining committed to a nuclear free energy system while still exporting energy will be difficult even for the well-equipped nation. While many SNP leaders tout the Scottish renewable energy resource as proof of the potential independent nation’s self-reliance, the export model of the former Saudi Arabia comparison is suspect. At least by itself, marine energy will not likely produce enough gigawatts to export significant amounts of electricity. Technically extractable resource figures are frequently revised, usually downwards. For example, a recent University of Oxford review determined that the 14 GW tidal energy resource touted by the SNP is inflated. Dr. Thomas Adcock, the lead researcher for the report, explains “There’s a huge amount of tidal power there, but it’s certainly no the case that Scotland will be able to export its tidal energy, which has been one of the arguments for Scottish independence.”⁵³ However, the Silicon Valley ocean energy hub approach may have more merit for the position of the independence advocates.

⁵² “UK Government Urged to Support Offshore Renewables,” *Scottish National Party*. Published January 24, 2014. Last accessed May 27, 2014. <http://www.snp.org/media-centre/news/2014/jan/uk-government-urged-support-offshore-renewables>.

⁵³ Connor, Steve. “Wave Goodbye to Hope of Tidal Energy Exports, Scots Politicians Told,” *The Independent*. Published July 10, 2013. Last accessed May 27, 2014. <http://www.independent.co.U.K./news/science/wave-goodbye-to-hope-of-tidal-energy-exports-scots-politicians-told-8698504.html>.

Scottish Energy Minister Jim Mather says that “Our seas have unrivaled potential to generate clean, green energy and bring jobs, investment and know how to Scotland.”⁵⁴ Whether the plans to exporting electricity come to fruition or not, Scotland has the opportunity to be the world leader in marine energy due to its abundant tidal and wave resource. By becoming a global hub for marine renewables, Scotland can export marine energy knowledge, technology, and machinery. Creating a domestic ocean energy supply chain could result in greater rewards than mere production. Aquamarine’s Martin McAdam sees the advantage in pursuing a Scottish marine energy cluster. He says “Wave energy has been invented here, is being tested here, and has the potential to be a home-grown global economic success... there is the potential to secure all the the manufacturing, construction and operations, and maintenance supply chain here in Britain.”⁵⁵ If a Scottish marine energy sector can be achieved, the investment in ocean energy will bring a high return.

Yet bringing the tidal and wave technology from the experimental stage to commercialization requires significant government support, just as the nuclear, offshore oil, and wind sectors required. Commercialization does not just happen based on potential; otherwise, the marine sector in Scotland would already be fully operational. McAdam noted that financial assistance is “vital” for the emerging

⁵⁴ Wolstenholme, Matt. “The Scottish Government Has Awarded a Shade More than £13m (\$19.7m) in Grants to Five Marine-Energy Projects,” *Recharge*. Published July 6, 2010. Last accessed May 27, 2014 http://www.rechargenews.com/news/wave_tidal_hydro/article1286250.ece.

⁵⁵ “Wave Energy Project Could Bring Hundreds of Jobs to the Western Isles,” *Aquamarine Power*. Published October 21, 2013. Last accessed May 27, 2014. <http://www.aquamarinepower.com/news/wave-energy-project-could-bring-hundreds-of-jobs-to-the-western-isles/>.

Scottish marine energy sector.⁵⁶ Other renewable energies have shown that reaching critical mass first is crucial to claiming the bulk of the sector's lucrative benefits beyond simply electricity. Speed counts.⁵⁷

The Scottish marine energy sector needs to continue to develop at a more rapid pace than competing nation's sectors in order to maintain a capital and knowledge advantage which spirals into more jobs and wealth. Although currently the leading location for marine renewables, the Scottish industry could easily lose its momentum and thus its advantage. If another country steps in with more rapid blue energy development, the sector could resemble the outcome of the British onshore wind industry. The U.K. "lost out" to other countries, namely Denmark, to be the hub of onshore wind production with the associated jobs and financial benefits. RenewablesUK outlined a comparative case study. The Danish onshore wind sector achieved the critical mass as the complete producer before Britain. From its investment in the sector, Denmark reaped 28,000 full time jobs while adding €1.5 billion to its economy each year. In comparison, the U.K.'s onshore wind factory production contributes only €0.6 million per annum to the British economy. The disparity came not from government investment in research and development for both countries spent a similar amount in that sphere. RenewablesU.K. suggests that the

⁵⁶ Wolstenholme, http://www.rechargenews.com/news/wave_tidal_hydro/article1286250.ece.

⁵⁷ "Scottish Islands Renewables Project: Final Report," pg. 75. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199038/Scottish_Islands_Renewable_Project_Baringa_TNEI_FINAL_Report_Publication_version_14May2013_2_.pdf.

Danish advantage arose from its anticipatory, early, and consistent incentive support for the sector.⁵⁸

Financially, the difference between possessing a resource in use and gaining full economic benefit is difficult to overstate. Scotland strongly wants to ‘win out’ in the international competition for marine energy by creating a thriving marine energy sector. The window of opportunity for establishing this ocean hydroelectricity hub will be short. Scotland has provided financial and political support for marine energy. Yet the cutting-edge energy companies face two significant barriers. First, a pervasive “lack of clarity” surrounds the future financial support of the industry.⁵⁹ Secondly, Scotland has not followed the Danish model of heavy grid and infrastructure development, such as the essential anticipatory electric grid connection. Instead, Scotland has largely let the market drive development of infrastructure capital. As such, delays have plagued planners on both the renewable technology and the grid infrastructure side. Currently, development on a notable scale has been largely stymied.

Any unnecessary delay is problematic for reaching the marine energy hub goal. For the marine energy sector to become cost competitive, a high level of deployment is necessary for the price of electricity to decrease. When the industry

⁵⁸ “Scottish Islands Renewables Project: Final Report,” pg. 71-2. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199038/Scottish_Islands_Renewable_Project_Baringa_TNEI_FINAL_Report_Publication_version_14May2013_2_.pdf.

⁵⁹ “Scottish Islands Renewables Project: Final Report,” pg. 72. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199038/Scottish_Islands_Renewable_Project_Baringa_TNEI_FINAL_Report_Publication_version_14May2013_2_.pdf.

arrives at the global economies of scale point, prices are expected to drop significantly, especially since the input of resource is considered to be free. To win the hub, Scotland needs to be the primary marine energy technology producer when the sector reaches the point of economies of scale. Scotland cannot attain the extensive level of localized deployment required without adequate grid connection to the resource, particularly to the resource-rich offshore areas adjacent to the northern Scottish islands.

The market-influenced delays will have longer than anticipated effects for there is limited capital stock, such as boats, equipped to develop offshore electric interconnectors. With this considered, Scotland should move to subsidize undersea cabling in excess of currently planned demand. In addition, cabling should first be built to island areas closer to the mainland grid so that Scotland can maintain its development lead and reach economies of scale, even if this gives preference to some regions over others in the short run. Since the strategy would reward some areas based on pure geographic location, reparations should be considered for the areas which would suffer from the interconnector delay.

Nevertheless, Scotland has made many noteworthy efforts to support the marine energy industry. Wavegen CEO Matthew notes that the government in Edinburgh is “probably the most engaged and supportive worldwide” in the marine energy sector.⁶⁰ The Scottish Government certainly values visible gestures of support. The shining jewel of Scotland’s dedication to marine energy is its £10 million Saltire

⁶⁰ Backwell, Ben. “Scotland has given the Go-Ahead for the World’s Largest Wave-Generation Scheme,” *Recharge*. Published January 29, 2009. Last updated November 25, 2012. Last accessed May 27, 2014. http://www.rechargenews.com/news/wave_tidal_hydro/article1280412.ece.

Prize. Named after the Scottish professor who designed early wave energy prototypes in 1970s, the Saltire Prize will be given to the marine energy project which produces the largest volume of electricity that exceeds 100 GW hours while operating continuously over 2 years. While companies can enter the contest until January 2015, five contestants have now been accepted into the competition: Pelamis Wave Power, Aquamarine Power, MeyGen Ltd., ScottishPower Renewables, and West Islay Tidal.⁶¹ The managing director of EMEC, Neil Kermode, describes the award as “the clearest possible commitment from the top that Scotland is serious about this industry. Scotland welcomes innovators, inventors and the inspired alike. This imaginative prize spells that out.”⁶²

While £10 million is quite the sum for a lay person, the winning purse is much less than the total cost of research and development of a new energy technology. ScottishPower Renewables project manager Richard Morris says that while the prize money would be nice, “winning the prize at the end is the ultimate goal.”⁶³ The Saltire Prize should be viewed as a good signal, but not the foremost, viable solution. The company that wins the prize, however, wins more than the money. In a literal way, the Saltire Prize enables the Scottish Government, firms, and regional developers the ability to see the technology winner, or at least the industry leader.

⁶¹ *Saltire Prize*. Last accessed May 27, 2014. <http://www.saltireprize.com/>.

⁶² “Neil Kermode, Managing Director, European Marine Energy Centre,” *Saltire Prize*. Last accessed May 27, 2014. <http://www.saltireprize.com/sector/neil-kermode-managing-director-european-marine-energy-centre>.

⁶³ “Richard Morris, Marine Development Project Manager, ScottishPower Renewables,” *Saltire Prize*. Last accessed May 27, 2014. <http://www.saltireprize.com/sector/richard-morris-marine-development-project-manager-scottishpower-renewables>.

Winning the £10 million gives the company a huge public vote of confidence and will serve as a significant advertisement.

The Scottish government has allocated other resources to the marine energy sector. The WATERS fund is designated to assist emerging tidal and wave energy development without giving a ‘blank check’ to the entire sector. Scottish Energy Minister Jim Mather says the funding is simply “another step on the road to a low carbon Scotland.”⁶⁴ In 2010, the fund awarded over £13 million to marine energy projects. Three of the five projects supported renewable energy on the islands. RWE Npower accepted £6 million to support its 4 MW Siadar project. Aquamarine took £3.15 million to accelerate its Oyster 2 development at EMEC. OpenHydro received £1.92 million to research more efficient methods for connecting devices into arrays.⁶⁵

Other observers press for a greater financial commitment to the emerging sector. Peter Madigan of RenewablesUK pleaded for government investment in the £150-200 million range by 2020. He contends that the financial needs of the industry are greater than realized. At the same time, he argues that marine energy is a huge prize worth the expensive commitment. He said “A properly capitalized wave and tidal sector could create 43,500 direct jobs and generate a potential £4.2 billion per year in revenue for the U.K. economy.”⁶⁶

Though Madigan’s estimate represents quite a prize, Scotland and the U.K. will not reach the marine sector aim without teamwork. While the Scottish

⁶⁴ Wolstenholme, http://www.rechargenews.com/news/wave_tidal_hydro/article1286250.ece.

⁶⁵ Wolstenholme, http://www.rechargenews.com/news/wave_tidal_hydro/article1286250.ece.

⁶⁶ Backwell, http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

independence efforts have potentially caused some bickering between the U.K. and Scotland over who pays for what expenses, both countries should evaluate their system of island charging. Lindsay Leask of Scottish Renewables says that the dream of a thriving, job-producing Scottish marine sector “could be lost unless... connection charges for Scotland’s island-based marine energy projects are set at a competitive level.”⁶⁷ In the U.K., transmitting electricity costs more as the distance to market increases. The pricing makes sense for a traditional system based on large centralized power plant production near urban areas. For the renewables-based system, the centralized charging regime is archaic. The distance charges greatly inhibits the renewables market, whose location must be based first on resource instead of proximity to population. In all regions of the U.K., but especially in Scotland, the greatest concentration of the renewable resource is in rural areas. Eliminating island charging could encourage the entire U.K. renewables sector, and spur on the efforts to develop the grid connection and technology requirements to make the marine sector viable.

To facilitate tidal and wave technology, every stakeholder agrees that grid expansion is urgently required. As reflected by the island charging practice, the U.K.’s national grid, again, is directed by the population location. From the power centers, electricity is shipped outwards to the rural countryside. The remoter regions of the country are served by an thinning grid with lower capacity. As mentioned, the strongest renewable resources in the U.K. are found at the windswept, wave-

⁶⁷ “Wave Energy Project Could Bring Hundreds of Jobs to the Western Isles,” *Saltire Prize*. Last accessed May 27, 2014. <http://www.saltireprize.com/news-events/wave-energy-project-could-bring-hundreds-jobs-western-isles>.

pummeled outskirts of the existing national grid. For significant renewable marine energy development to occur, the philosophy of the grid pattern must be reversed. Right now, the grid's wires do not have the capacity to meet the significant renewable resource. The grid needs to take a decentralized, outwards to inwards approach. Until this happens, the tidal and wave development will be stymied by a lack of electrical bandwidth.

The lack of space serves as a huge disincentive to wave and tidal developers. Why deploy an array if the electricity cannot reach the market? Simultaneously, why build an expensive offshore electric grid if the tidal and wave technology are still immature technologies? No one feels these renewable energy pangs more acutely than the Scottish Islands.

CHAPTER 2: THE ISLANDS

Nearly forgotten in the far British north, Scotland's isles hold a mystic that permeates the region's air, land, and sea. Yet these remote places are at the forefront of the modern British environmental push. Simply, the Scottish Islands are the cornerstone of the nation's renewable energy goals. At the same time, Scottish leaders realize that fostering an economically healthy rural area creates a strong nation. Marine energy could point to the way to satisfying both aspirations, while helping the country meet its environmental goals. "My vision is for a rural Scotland that is growing in prosperity and in population" explains Richard Lockhead, Cabinet Secretary for Rural Affairs and the Environment. He continues "as we move to meet the climate change challenge, I want to see more people able to live and work in our countryside."⁶⁸ As an outline for the SNP's vision for a green nation, his sentiments point to the crucial location for Scottish environmentalism: the rural, remote coastal areas. The life-blood of economic and population regeneration in remote Scotland is green energy efforts. With the potential for a strong wind and marine power industry, the remote islands could sustain a vibrant Scotland. With its limited solar resources and wind construction concentrated on mainland Europe, Scotland images the production of a marine energy sector to be either salvation for the more hardest-pressed rural regions or the path to continued prosperity in the more dynamic rural regions.

⁶⁸ "A Greener Scotland....," *Scottish National Party*. Last accessed May 27, 2014. www.snp.org/vision/greener-scotland.

The three regions that are classified as remote rural Scotland -- the Islands, the Highlands and remote south Scotland -- face obstacles to continued community sustainability. Cost of living measures are a good place to look for context. The U.K. standard for Minimum Income Standard (MIS) is defined as “more than just food, clothes, and shelter. It is about having what you need in order to have the opportunities and choices necessary to participate in society.” Meeting the MIS standard can be a struggle for many remote Scotland residents, particularly on the islands. For all the surrounding beauty, the remote Scottish Isles are demanding places to live well.

A 2013 report, “A Minimum Income Standard for Remote Rural Scotland”, catalogues the extra costs of living for the isolated communities which contribute to the regions’ social and economic fragility. In total, the study states the expected. Living in these regions is more expensive. Compared to urban Britain, the estimated cost of living ranged from 15% to 40% greater for the same quality of life. Within the three regions, a large distinction in the MIS was made between town and more distant, isolated settlements. The greatest difference in rural Scotland was identified between mainland and islands communities. Transportation costs and household fuel costs were the primary drivers of the more expensive bundle required for the cost of living. In these areas, energy is both more expensive and more necessary.

Life has never been easy on a Scottish island. For the past 50 years, studies of the region have exhibited “the need to help [the islands] reach their full potential.” The report suggests that “tackling” individual higher costs could greatly help the

region. Rising energy costs are expected to continue to place great pressure on the communities' sustainability. For this reason, energy prices should be a prime target. The hope is that renewable marine energy can alleviate the energy stressor on communities in the islands and even serve to reduce fuel poverty.⁶⁹

In Scotland, fuel poverty is defined by spending greater than 10% of disposable income on household fuel. On average 28% of Scottish households experience this cost burden. The islands face a much higher rate of fuel poverty. Shetlanders, boosted by oil and gas, have only a slightly higher rate than the national average for fuel poverty at 35%. However the density of fuel poverty is heavily concentrated in the more remote Shetland islands. The pattern is more evident in Orkney, with its 50% rate of fuel poverty and the 58% rate in the Outer Hebrides. With fossil fuel prices on a long term rise, fuel poverty will increase in the islands unless the renewable electricity sector is developed.⁷⁰

On the islands, price is not the only obstacle to energy security. Reliability is key. The islands suffer from the frequent electricity blackouts. One respondent stated that “power cuts are a way of life here.” The National Grid and the British Office of Gas and Electricity Markets (OFGEM) now warn that these blackouts will be increasing. SNP Energy Minister Fergus Ewing stated that “Scotland’s record levels of renewables generation are increasingly important to keeping the lights on across

⁶⁹ “A Minimum Income Standard for Remote Rural Scotland,” *Highlands and Islands Enterprise*. Last accessed on May 27, 2014. <http://www.hie.co.uk/regional-information/economic-reports-and-research/archive/a-minimum-income-standard-for-remote-rural-scotland.html>.

⁷⁰ “Scottish Islands Renewables Project: Final Report,” pg. 75. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199038/Scottish_Islands_Renewable_Project_Baringa_TNEI_FINAL_Report_Publication_version_14May2013_2_.pdf.

these island.”⁷¹ Renewable energy can thus provide energy security at the community level on the islands.

Personal travel in the islands is a large component of the extra expense. Public transport is limited. At least one car is deemed essential for remote rural life. The high cost of petrol and extensive traveling required for shopping and leisure cover part of this, yet the greatest expense is the fuel needed to drive to work. The average commute distance for islanders was estimated to be around thirty miles, one way. Many of the surveyed residents of Orkney and Shetland also had to incorporate daily ferry crossing to a considerably higher expense for their commute. Beyond the personal level, higher delivery charges raise prices for all sorts of consumer goods, from food to clothes to Christmas gifts.

Compared to the average English home, remote Scottish residents face “very high” heating costs. In the most dramatic example, a single person living in a Northern Isles settlement faces a 184% higher average domestic heating bill. The study contends that the lack of access to gas mains in rural remote Scotland is the primary cost driver. Instead, towns rely on electric storage heating, while private houses in smaller areas often use heating oil. Back-up electric generators are frequently needed either to supplement the electric storage heating of the towns or for

⁷¹ “Conference Highlights Our Renewables Strength,” *Scottish National Party*. Published October 18, 2013. Last accessed May 27, 2014. <http://www.snp.org/media-centre/news/2013/oct/conference-highlights-our-renewables-strength>.

frequent widespread power cuts due to stormy weather. All the while, the wet, windswept climate of the islands makes the heat, while expensive, essential.⁷²

The January 2011 area profile of the Highlands and Islands places the Orkney Islands, Shetland Islands, and the Outer Hebrides into context with the rest of Scotland. On the bright side, the islands have “particularly favorable” indicators in quality of life measures such as crime, vandalism, and class size in schools compared to the rest of Scotland. Employment is thriving in some of these regions. The 447,043 residents of the Highlands and Islands in 2009 experience an unemployment rate “consistently below” the rate in Scotland. A growing seasonal tourism industry and large public sector employment have kept the area more insulated from the recent worldwide recession. The region also has a significant rate for self employment, particularly due to crofting, fishing, and tourism. The region is hardly homogenous, however. Though Orkney and Shetland thrive, the Outer Hebrides has high unemployment.

The unemployment rate fails to tell the whole story. Overall, the remote areas are less prosperous than the rest of Scotland. In all three regions, housing options are limited. Percentage-wise, house prices have grown more slowly than the national average in Orkney and the Outer Hebrides, though prices have rapidly increased in central Shetland. In these regions, the average income is approximately 9% lower than the nationwide average. Part of this is due to a significantly lower proportion of employment in the financial and energy sectors compared to the rest of Scotland.

⁷² “A Minimum Income Standard for Remote Rural Scotland,” <http://www.hie.co.uk/regional-information/economic-reports-and-research/archive/a-minimum-income-standard-for-remote-rural-scotland.html>.

While Orkney, Shetland, and the Outer Hebrides have comparable gross value added for each full-time employee in the construction and service sectors, the manufacturing sector varies significantly among the islands. Manufacturing jobs in the Outer Hebrides only add £29,000 each to the economy while the same in Shetland adds £47,000. Orkney beats both regions with £67,000 per manufacturing job. The Highlands and Islands region also reveals a gendered employment sector. Over 90% of the female workforce is confined to the service industry. The region sorely needs a high paying, gender diverse sector. Marine energy could fill this void.

The low average pay cannot be adequately labeled as only a skills problem. The educational attainments are considered as “exceptionally high” in the three island chains. However, the strong primary and secondary school performance is tempered by a large number of graduates departing to other areas of Scotland for school, typically remaining away for work. The temptation to depart has plagued the area for decades. Still, some regions are showing promise for reversing the trend. In fact, the population in the Highlands and Islands region has grown by 3.14% since 2001. Yet, the gains are primarily in the Inner Moray Firth. Almost by itself, Inverness has outstripped all other regions in population growth. The population on Orkney grew by 3.9% from 2001-2009 to nearly 20,000 residents. Shetland experienced a slight growth during that time while Inne Gall, Gaelic for the Outer Hebrides, declined in population by 1%. For the Outer Hebrides, the decline reinforces a steady long-term

population decline. Throughout, the Highlands and Islands region's population is skewed elderly as many younger residents continue to leave.⁷³

For the Scottish isles, the offshore resource is immense. The overall renewable resource from the islands is virtually untapped for only 55 MW capacity has been installed as of May 2013. Whereas onshore wind has 2.8 GW of potential, the technically extractable marine energy resources of tidal and wave energy are 4.5 GW and 5.6 GW, respectively. Of course, offshore wind is a considerable resource to be considered. Sans offshore wind, the following three paragraphs delineate the resource by archipelago. In summary, the Outer Hebrides are the wave power hub, Orkney has the greatest tidal resource, and Shetland lead with the wind potential.

Of the island chains, the Western Isles "in particular" is blessed with "unparalleled" wave resource. From a Npower Renewables study, the Outer Hebrides have technically -- if not practically -- 4.8 GW of wave potential with an associated 685 MW tidal energy resource. Also, the Outer Hebrides have the potential for 550 MW of electricity from onshore wind.

With its location adjacent to the Pentland Firth, Orkney is rightly known for its tidal power resource. From a 2005 Aquatera study, Orkney has an astounding 1,462 - 3,571 MW potential for tidal stream. The tidal resource makes the islands' considerable 101 - 226 MW wave potential and 265 MW of onshore wind resource seem paltry in comparison.

⁷³ "Area Economic Profiles 2011," *Highlands and Islands Enterprise*. Last accessed May 27, 2014. <http://www.hie.co.uk/regional-information/economic-reports-and-research/archive/area-profiles.html>.

Wind dominates the Shetland renewables scene. The northernmost British islands have a potential for 1,980 MW of onshore wind development. From a 2005 Aquatera study, The Shetland Islands have a reasonable 248 MW capacity for tidal energy and with a 347 - 596 MW capacity for wave power.⁷⁴

Before demanding that every last MW on the Scottish islands be exploited, Scottish leaders need to consider the effects from expanding an industrial coastline beyond the harbors. What would the ripple effects be from a fully deployed renewables sector in Scotland? One impact from the developments could effect the essential tourism industry. Scottish prosperity relies on vacationers. The numbers speak for themselves as tourism comprises 9% of the Scottish workforce and £11 billion in associated revenue. Away from the tartan-tattered Royal Mile and outside of dark stone castle walls, natural beauty is a premier attraction. Over 90% of Scots agree that scenery was an important aspect for choosing the location of their holidays. The distant ocean horizon and green hills of Shetland, Orkney, and the Outer Hebrides are evocative scenes. Waves crash on the rocky shores as marine mammals swim past via the swift tides. Over each island, gusts of wind drown out the background noise. Visitors love the three archipelagos for the feeling of peaceful remoteness.

The islands' early renewable energy developments have been driven by wind. In response, Scotland's national tourism organization, VisitScotland, has investigated

⁷⁴ "Scottish Islands Renewables Project: Final Report," pg. 13-15. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/199038/Scottish_Islands_Renewable_Project_Baringa_TNEI_FINAL_Report_Publication_version_14May2013_2_.pdf.

the impact of these twirling white pillars on tourism. In its wind farms position statement, VisitScotland cautiously suggests that wind developments have only a “limited” impact on tourism. From its survey, the organization notes that around 80% of Scots view the presence of wind turbines as an irrelevant variable for guiding their vacation’s destination. The new development even proved to provide some attraction as a curiosity. Almost half of the responses even expressed interest in touring a wind farm.

Like the respondents, the agency recognizes the importance of renewable energy, but seeks to “sensitively” guide those developments to proper spots. The strategy would be wise for when asked whether turbines were eyesores respondents were quite divided, with a slight tend towards disagreement with the statement. In short, VisitScotland admits that does not want to, nor can it, oppose renewable energy development. Instead, the agency seeks to minimize impact.

For its merit, the VisitScotland report is still quite limited. The report asks within a national scale. Respondents imagined the presence of their favorite locations with windmills. Travelers enjoy scenery differently. A bird watcher might desire a clear sky while a golfer could be glad to have a structure to orient a drive’s bearings. The poll is not location specific. Wind farms could have a more significant impact on the islands’ visitors than the tourist horde in Edinburgh. By polling Scottish opinions, VisitScotland determined preferences of, perhaps, a voting population but not the entire mass of tourists. By contracting an online company, the respondents were skewed to young people due to internet behavior and access. In part captivated by the

allure of nature in the wild or remote, visitors from beyond Scotland may have a lower tolerance for landscape alterations than Scotland's residents. International visitors have less invested interest in Scottish renewable production. The Scottish people obtain both a local and national benefit from green energy while the visitors only profit from the development's global benefits. Even if the preference percentages equaled, a nearly one-fifth section of the vacationing population is quite significant, especially for businesses surviving on thin margins, as is common on the islands.

The argument that renewable development has no effect on tourism is disingenuous. The massive turbines of wind farms impact a large region. I have heard people at St. Andrews in Fife swear that on a clear day they can see the eyesore of offshore wind farms off Northumberland in England. In my experience, seeing an offshore wind farm in the distance, as I did from the hamlet of Uig on the Isle of Skye, can be peaceful. Opinions aside, the presence of wind farms is undoubtably noticed. As for whether the polled population has seen a massive wind development, VisitScotland notes that 77% of Scots have seen a wind farm on vacation. No distinction was made between whether the wind farm was seen while speeding by on a train from a distance or from a close perspective. As documented in the film *Windfall*, proximity to turbines changes opinions. In this case, imagination may mislead. For these reasons, developers need to move cautiously and be very careful with specific site selection with regards to renewable development.

Could wind be replaced by tidal or wave energy? The visibility impact of the two resources are far smaller than wind turbines. For the foreseeable future of the

changing energy mix at the macro-level, tidal and wave energy will not displace wind. Instead, the tidal and wave industry will be additive. Thus for the islands, the cumulative impact of wind and marine energy should be considered. The micro-renewable strategy is not driving tidal and wave research and development. As the current industry drive instead eagerly anticipates the profitable export model, the islands should plan for ocean front commodification. The prospect of huge arrays facilitates the effort to bring the technology to both maturity and cost effectiveness.

With this in mind, VisitScotland and the islands need to plan for the tourism effect of the marine renewables. With the importance of ease in maintenance, the leading tidal turbine designs such as Marine Current Turbine's SeaGen protrude a pillar above the ocean's surface in the shape of an plastic thumbtack instead of being completely submerged. Pelamis' Sea Snake floats atop the water like thick red lane ropes. At the Orkney test center, both tidal and wave devices are present relatively near the shore. Wind can be placed further offshore. Some surface space could possibly be shared. On-shore wind farms could be shelved in favor of tidal, wave or even off-shore wind. The incoming wave and tidal sector to remote Scottish scenery provides an opportunity to poll visitors and locals alike for preferences specific to location. Advancing and narrowing VisitScotland's broad-brush polling is key to carefully designing a viable and profitable marine spatial plan. At the local level, wind and marine renewable projects should not be rushed until such a plan has been formed.

Regardless, the renewables industry is coming quickly to the Scottish islands.

In particular, the marine energy sector is set to expand in the coming decades. Island by island, the following chapters will examine the story of marine renewables thus far in Scotland.

CHAPTER 3: ISLAY

Whisky connoisseurs enjoy fireside drams of the famous peaty Scotch whisky on the island of Islay as they look across the windswept sea. The “Queen of the Hebrides”, the island is a prosperous farming and fishing location at the southernmost tip of the Inner Hebrides. With significant renewables resource, Islay was almost selected as the site for the Scottish marine energy testing center. Although the island lost that bid, Islay is likely to experienced the range of the burgeoning marine sector’s stages from the prototype, to the medium array, and to full-scale deployment. All in all, Islay serves as a microcosm of the Scottish experience in blue energy.

Just down the road from Port Charlotte at the Rhinns of Islay, the world’s first grid connected wave energy device lies beneath a large concrete bunker. The shore-based device established the Scottish firm Wavegen as the leader in wave energy technology when the machine became attached to the local electricity grid in 2000 at the Limpet site. In addition, the site has tested several other prototypes, including some very early wave device generations designed by engineers at Queens University Belfast. Though the Wavegen project reached its initial goals, the Limpet test location is now designated for closing.

“The technology is proven” Islay resident Kevin Wiggins explains. “Wave power is a reliable technology, practically runs itself.”⁷⁵ He should know. He has serviced the Limpet oscillating wave energy turbine for years. Usually, the only

⁷⁵ Kevin Wiggins (Wavegen mechanic) in discussion with the author, June 2013.

maintenance required was replacing the overhead lightbulb in order to see to check the monitors.

Although the Limpet site received a lot of good press when it opened, the testing site has been relatively neglected. Wiggins admits that a lack of political interest has hurt. He says “That’s one thing that’s really bothered me. No one in the government has come to the site. I’ve contacted the local MSP on five separate occasions. No reply, simply disgraceful.” To speculate, maybe the money involved with Limpet site just was not enough.

As a research and development site, the testing on Islay at the Limpet bunker has succeeded. The Wavegen device’s reliability rose to 90%. The improvements met a key goal for the wave technology. Wavegen’s chief executive Matthew Seed says “if things are unreliable, people won’t invest in them.”⁷⁶ However, as the Limpet site proves, device reliability is not the only hurdle for large scale wave energy deployment of the oscillating water column technology.

The Limpet site has been in trouble before. In the mid-2000s, the wave energy location nearly closed as Wavegen almost went under financially. The massive German firm Voith swooped in to purchase the spot. Chief executive of the marine energy testing center at the U.K.’s National Renewable Energy Center (NAREC) Andrew Mill says that marine renewables “need investment on balance sheets to get things started” and that “when you see the big players coming in that you will start to

⁷⁶ Backwell, http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

see things happen.”⁷⁷ The interest and finance from a major energy corporation were seen as evidence that the marine industry was rising on Islay.

Yet, the entry of a large firm into the marine energy market is no guarantee for success. The initial Voith-inspired optimism plateaued and has since declined. Now, the German multi-national is expected to close the site. When a site sponsored by such a company is designated to close that is a troubling sign. Even worse for Scotland, Voith plans to “pool” its wave energy department in Heidenheim, Germany. While the move would only effect a few Islay residents directly involved in the Limpet site, the consolidation will shut down Wavegen’s located in Inverness, capital of the Highlands region, impacting 18 employees.⁷⁸

The reason may be that large investors such as Voith are skeptical of the size of scale for breakwater wave turbine technology. In the big picture, a few breakwaters may seem a pittance for a massive international firm. For near shore devices, the potential profits are tiny compared to that of a traditional hydroelectric dam. Yet, the limited extent of breakwater technology was apparent when Voith first purchased Wavegen. Grid constraints, particularly with the Wavegen site in the Outer Hebrides, motivated Voith to retract from Scotland.

Voith can depart, but Islay still remains. Islay residents preferred not to let the site go to waste. They had to wave goodbye. The Wavegen site proposed to close in September 2013. Wiggins says the island community has tried to step in and claim the

⁷⁷ Backwell, http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

⁷⁸ “Scotland’s First Wave Firm, Wavegen, in Trouble,” *BBC News Highlands & Islands*. Published March 4, 2013. Last accessed May 27, 2014. <http://www.bbc.com/news/U.K.-scotland-highlands-islands-21657133>.

site. Even for the world's oldest grid connected site, Islay did not have enough time. "We didn't know Voith was planning to shut it down until February. That wasn't much time to put together a portfolio and plan to take over the site." Still, the island made an effort to buy the site. "The Islay Energy Trust (IET) tried to purchase the Limpet, but it didn't work. The problem was the liability of decommissioning. It would cost three quarters of a million (£) to decommission. It's built of concrete. You can't just cover it over."

When construction first occurred, the Islay community was largely supportive of the Wavegen site. Wiggins, at least, recalls little opposition to hosting the site. Yet the result seems a bit disappointing. He observed that "Initially there was lots of employment on the civil side. The promise [of jobs] came through, though never a huge amount." Since, the island's optimism in wave energy has diminished over time as the community impact from the Limpet proved smaller than hoped.

As the Limpet tries to cling to the grid like its sea snail namesake, marine energy observers should take note of its struggles. Usually, the state of the technology is blamed for lack of marine energy deployment. Yet economic forces such as low profitability may constrain marine energy more than conveniently admitted. Longtime Islay resident Archie McTaggart explains, recalling the first wave energy explorations on the island. "The engineers at Queens University Belfast said we can do anything with enough time and money. That was twenty-five years ago." Time has passed, but the money has only recently begun to be available.

Abandoning the resource of the oceans seems counterintuitive to islanders. Wiggins says “When you live on an island you are constantly aware of the potential. You see how much power the sea has. It’s hard to see why it’s not used more. It makes sense to use sea energy, absolutely.”

Though Limpet closes, ocean energy is coming to Islay’s waters. New renewable energy projects are entering the conversation to take advantage of Islay’s close connection to mainland Scotland. Building an adequate interconnector can thus occur relatively quickly and cheaply. Wave power may have been the first to arrive, but tidal and wind developments are set to sweep away Islay’s wave legacy.

The shift of technology on the island may be representative of larger trends. Though Scottish politicians are known to be almost vociferous in their support for renewable energy, wave power seems the forgotten technology. Wiggins says the Scottish government is “not so keen on wave technology, much more interested in wind and tidal power.” With two important tidal projects and one large wind deployment set to arrive, Islay may signal the overall direction of the marine renewables industry.

The first of the two proposed tidal developments fulfills a critical transitional stage for the industry. ScottishPower Renewables has gained consent for building a Demonstration Tidal Array.⁷⁹ The proposal won an Energy Globe Award in 2013. According to *Illeach: The Independent Newspaper of Islay & Jura*, the 10 MW

⁷⁹ “Sound of Islay,” *ScottishPower Renewables*. Last accessed May 27, 2014. http://www.scottishpowerrenewables.com/pages/sound_of_islay.asp.

project represents the “essential intermediate step ahead of large scale deployment.”⁸⁰ By filling in this key developmental stage, the Sound of Islay project received £17 million of European Commission funding, gathered from penalties on polluting industries.⁸¹

Once again, Islay has attracted international attention for its groundbreaking marine renewable efforts. ScottishPower Renewables’ Barry Carruthers said “We are delighted that our plans for a pioneering tidal power project in Scotland have received international recognition... Projects like Islay will be critical in allowing the whole industry to have greater understanding of the challenges involved in generating electricity from the tides, before larger projects are deployed in other locations around Scotland and across the world.”⁸²

Yet why is ScottishPower so willing to occupy the intermediate stage? The company has partnered with Andritz Hydro Hammerfest Strom to test a tidal array under relatively stable conditions. While Hammerfest Strom successfully deployed a prototype, the HS1000, at EMEC in 2011, the company wants to establish the device’s success in an array setting in open water.⁸³ The Sound of Islay development will take advantage of the intensified tidal flow from the straight between Islay and its neighboring island, Jura, while being located close to shore for electrical transmission. The two islands act as a buffer to crossing waves which allows the

⁸⁰ *Illeach: The Independent Newspaper for Islay and Jura*. May 18, 2013 edition.

⁸¹ “Tidal Energy Projects Share £30m in European Funding,” *BBC News Scottish Business*. Published December 18, 2012. Last accessed May 27, 2014. <http://www.bbc.com/news/U.K.-scotland-scotland-business-20777294>.

⁸² *Illeach: The Independent Newspaper for Islay and Jura*. May 18, 2013 edition.

⁸³ *Illeach: The Independent Newspaper for Islay and Jura*. May 18, 2013 edition.

developmental stage tidal device to stay more secure and require less maintenance.

While the tidal race is strong, the narrow expanse of the sea between the islands constrains the development scale. After room for boat traffic is considered, the inter-island area has only so much space left for turbines. The Sound of Islay project can hold an approximate total capacity of 10 MW.⁸⁴

A more ambitious project off Islay's shores shows that the tidal sector is truly nearing the technological maturity needed to expand to the full commercial level. DP Marine Ltd. (DPME) and DEMA Blue Energy (DBE) are proposing a joint project to develop a tidal energy project approximately 6 kilometers off the Rhinns of Islay. The two companies bring considerable marine energy expertise to their West Islay Tidal Project. As a subsidiary of DP Energy, DPME draws from its parent company's two decades of renewable energy experience. Founded in 2008, DPME aims to develop tidal and wave energy sites at the global scale. First, the company looks to achieve technological and expertise maturity in the U.K. and Irish waters for which Islay occupies a strategic middle location. For its role in the partnership, DPME will focus on site development and achieving project consent. On the other side, DBE's parent company, DEMA, is an established leader in marine construction based on its offshore wind experience. From its wind development, the company has specialized capital that is transferable to the developing tidal and wave energy. Significantly for the blue energy subsidiary, DEMA has construction experience with tidal energy. The company helped commission the world's first commercial tidal energy deployment

⁸⁴ "Frequently Asked Questions" *West Islay Tidal*. Last accessed May 27, 2014. <http://www.westislaitidal.com/faq.html>.

with the SeaGen device in Strangford Lough in Northern Ireland in 2008.⁸⁵ The cross-over from the wind sector to marine sector as experienced by DBE suggests that the hope and focus on skills transfers from the existing offshore oil and gas industry is misplaced. Instead, skills among renewable energy efforts are compatible and even complimentary. The finding suggest that renewables should be developed within clusters.

The trick for tidal commercialization is cost effectiveness. The West Islay Tidal location is an ideal place for such marine development. Importantly, the site can be expanded in the future. The west coast of Islay has ample navigation space. The project managers estimate an array of nearly 200 turbines with the capacity of 400 MW can eventually be deployed. Also, the location seems surreptitious as it lies just further offshore from Portnahaven, the site of the early leader in wave technology, the Limpet. On the other hand, the open sea site is open to the strongest tempest the North Atlantic swell can deliver. West Islay Tidal exhibits brazen confidence in future turbine design. The group states “ultimately, engineering solutions can be provided to ‘almost’ anything.”

As mentioned previously, tidal stream power is very site specific. One reason Islay has returned to the tidal energy developer’s radar is the relatively straight but strong flow of the tides to the west side of the island. In this western coast area, the tide has a nearly 180 degrees bidirectional flow. The flow direction helps reduce engineering obstacles. Other similarly swift tidal sites have variations of up to 30

⁸⁵ “Frequently Asked Questions” <http://www.westislaytidal.com/faq.html>.

degrees in their ebb and flood tides. The west coast of Islay presents a simpler tidal race for which early generation tidal devices can experiment with greater confidence.

The joint venture is proceeding with a different strategy than most other contemporary developments. Neither company is committed to a particular company's turbine for the site. The Rochdale Envelope approach to environmental impact assessment for development allows for project flexibility. With the leeway, West Islay Tidal can try to pick a winning turbine through a "Technology Neutral Approach." The only specification given is that the chosen turbine is based on an open rotor design. Realistically, the requirement limits the choice to three competitors: Siemens MCT, Alstom TGL, and Andritz Hammerfest.⁸⁶ Though the group has to monitor a wider span of technologies, West Islay Tidal is looking for the technology that can be successful in an array. The decision to go with flexibility is in marked contrast to many early and currently developed plans such as the deployments at Orkney with EMEC, in Canada at the Bay of Fundy and Race Rocks sites, and the longer-term MCT device at Strangford Lough. Essentially, the previous projects were designed less to produce power and more to test design strength, durability, and functionality.

As such, the West Islay Tidal project heralds the onset of development at the commercial level. Industry observers will be intrigued by the project's verdict on visibility. The company is considering both subsurface and surface piercing devices. The former has the scenic advantage as well as the ability to operate in depths

⁸⁶ "West Islay Tidal," *Saltire Prize*. Last accessed May 27, 2014. www.saltireprize.com/competitors/west-islay-tidal.

exceeding 40 meters. At that level, the strength needed to secure a surface piercing device in a strong tidal race is too expensive and inefficient. However, the first phase of the development is aimed at a site with an average depth of 30 meters. Considering DEME's experience with Siemens Marine Current Turbine's above water device, a surface piercing turbine seems to be the leading choice. The maintenance advantage of MCT's above water SeaGen is very significant for marine renewables. No device is currently expected to be indestructible. In fact, developers are seeking to find the weak points. However, the companies do want to be able to correct the design problems easily. The ability to weather the rough ocean environment is the number one design problem in marine energy. Accessibility for maintenance allows the device's vulnerability to be mitigated.

When compared to offshore wind turbine's motion, circumference and height, a stationary tidal structure presents a small visual impact for the electricity return. For example, MCT's SeaGen rises to 21 meters above the surface while the proposed SSE Islay wind farm turbines are 151 meters high.⁸⁷ Still, the visibility burden of the West Islay development will fall on a small segment of Islay's residents. The village of Portnahaven will bear the majority of the visual and fishery space impacts of the proposed array. At the same time, the primary maintenance facilities will be located in Port Ellen, and as such, the majority of the contracted jobs. In a community meeting in Portnahaven, DPE's project manager, Blair Marnie, promised vaguely that "something would come back to the community."⁸⁸ Ironically, if the community

⁸⁷ "Frequently Asked Questions" <http://www.westislaytidal.com/faq.html>

⁸⁸ *Illeach: The Independent Newspaper for Islay and Jura*. April 6, 2013 edition.

wants to benefit significantly from the development, then Portnahaven should hope for larger deployment -- and more adverse impacts. Basically, more boats will be needed to do maintenance if there are more turbines in the water. *Illeach* reports that though the community appreciated the dialogue with the developers, the “general opinion” of the attendees was that direct benefit to the island, especially to Portnahaven, would be slim.

By directly selling energy to the islands, developers could help appease the islanders’ concerns. Although DPE understands this benefit of this direct sell, the existing grid sanctions will direct the produced capacity towards the mainland.⁸⁹ Nevertheless, Islay is mobilizing to maximize community benefit to blue energy development. In May 2013, the Bowmore Village Hall hosted Dave Hollings of Cooperative Mutual Solutions to outline how to organize a proposed Islay Energy Community Benefit Society.⁹⁰

For now, wind has the edge on Islay. The wind advantage could be very beneficial to Islay’s tidal aspirations. Though designed by a separate developer, the SSE Islay Wind Farm will, capacity-wise, will be much larger than either tidal project. SSE plans to deploy turbines with the total capacity of 690 MW, as compared to the West Islay Tidal’s development’s 30 MW.⁹¹ Like a fisherman hauling in a fresh catch, the wind project could draw the needed electrical capacity to Islay. The wind farm’s consent signals the imperative for grid connection. In this way, the Islay Wind

⁸⁹ *Illeach: The Independent Newspaper for Islay and Jura*. September 8, 2012 edition.

⁹⁰ *Illeach: The Independent Newspaper for Islay and Jura*. May 4, 2013 edition.

⁹¹ “Frequently Asked Questions,” <http://www.westislaitidal.com/faq.html>

Farm will help to facilitate the tidal energy developments. Perhaps wave energy endeavors will soon follow as well.

CHAPTER 4: THE OUTER HEBRIDES

A blue and yellow float won the 2013 Hebridean festival parade. The D.R. Macleod lorry was graced by a sign reading “Western isles can’t export electricity until Minch Interconnector Cable gets green light from OFGEM. So the Gravir steams on to the National Grid.” The Gravir was represented on the lorry bed by a sky blue boat named the MV Interconnector Gravir. On one side of the boat, a captured cattle grid symbolized the national grid. On the other, the OFGEM headquarters was portrayed as a hesitant shack led by a pair of bikers wearing sheep heads, portraying the “common grazings Home of Green Energy.”⁹² As seen in the parade, the Outer Hebrides holds a grudge towards the market players that have prevented construction of the new interconnector, the Gravir, from reaching the islands. Without the grid connection, the islands’ vast renewable resource will remain untapped, to the region’s dismay. Though mocked in jest and exasperation during the parade, in Innse Gall renewable electricity is a serious business.

Far off into the Atlantic swell lies the strongest outpost of Scottish Gaelic culture, Innse Gall. Also known as the Western Isles or the Outer Hebrides, the area has been labeled by the Highlands and Islands Enterprise (HIE) as “economically fragile.”⁹³ Renewable energy is viewed as the best solution for enhancing the area’s economy. While the creative industry, notably the world famous Harris Tweed, and

⁹² McMillin, Thomas N. Summer 2013. Personal photo.

⁹³ “The Outer Hebrides,” *Highlands and Islands Enterprise*. <http://www.hie.co.U.K./regional-information/area-information/outer-hebrides/>.

tourism sector are essential to the islands, the two sectors face limited prospects for significant expansion. Thus, securing jobs to accompany the energy production is an imperative for the Western Isles sustainability.

In anticipation, the HIE has invested heavily in equipping the region for development as a renewable energy hub. The islands' only industrial site of significant size, Arnish Business Park, has been a target spot for attracting energy development. In the past 11 years, HIE has invested nearly £15 million in the site. Recently, HIE modified the oil fabrication facility at Arnish into an updated industrial estate catering to both oil and gas and renewable development. Ideally, the site, just 6 kilometers north of Stornoway, will be attractive to companies interested in manufacturing devices onsite. The Outer Hebrides is trying very hard to recruit, even offering discounted business rental rates of up to 100%. HIE's Innse Gall Project Manager states that "Arnish is a vital location in the development of Scotland's renewable energy industry. Having the right infrastructure in place is an important factor for ambitious businesses identifying where to locate."⁹⁴ The business park has had some success. Burntisland Fabrications, or BiFab, completed some of the fabrication work on the Hammerfest Strom tidal device and the Oyster II wave device.⁹⁵ Conceivably, these small contracts are a sign of what is to come for Innse Gall. The area is trying its best to take advantage of its potential to be massive blue energy center.

⁹⁴ "Arnish," *Highlands and Islands Enterprise*. Last accessed May 27, 2014. <http://www.hie.co.uk/regional-information/regionally-significant-investments/projects/arnish.html>.

⁹⁵ "Tidal," *Burntisland Fabrications Ltd*. Last accessed May 27, 2014. <http://www.bifab.co.U.K./view/tidal.aspx>.

The Outer Hebrides is also preparing a renewables skills and knowledge base on the main island of Lewis. The island's Lews Castle College has developed a renewable energy research center named Greenspace.⁹⁶ Aquamarine Power has likewise teamed up as Lews Castle's the industry partner for the Hebridean Marine Energy Futures project. The project hopes to define the Hebrides as a wave energy knowledge center as well as identify practical site-specific information for developers.⁹⁷

Ideally, the efforts will make the decision for marine industry to locate onsite in the Outer Hebrides a convenient one. Yet for all its striving, the peaceful Outer Hebrides faces several huge barriers to developing their exceptional renewable energy endowment. As Aquamarine's McAdam notes, "The vast majority of the U.K.'s wave resource lies in remote locations, where economic opportunities are few. Wave energy offers a real opportunity for these communities."⁹⁸ The Siadar wave energy saga on the northwest coast of Lewis reveals the difficult barriers to achieving a cutting-edge technology development in a remote area.

The original Siadar Wave Energy Project was planned to place the Outer Hebrides in the forefront of marine renewable development. In fact, the project seemed to signal hope to the entire wave industry. Paul Cowling, the managing director of Npower Renewables, stated that the first Siadar project consent was a

⁹⁶ "Outer Hebrides - Key Sectors," *Highlands and Islands Enterprise*. Last accessed May 27, 2014. <http://www.hie.co.U.K./regional-information/area-information/outer-hebrides/key-sectors.html>.

⁹⁷ "Partners and Funders: Lews Castle College," *Aquamarine Power*. Last accessed May 27, 2014. <http://www.aquamarinepower.com/about-us/partners-and-funders/lews-castle-college/>

⁹⁸ "Wave Energy Project Could Bring Hundreds of Jobs to the Western Isles," <http://www.saltireprize.com/news-events/wave-energy-project-could-bring-hundreds-jobs-western-isles>.

“milestone” moment for marine energy.⁹⁹ In a presentation directed by RWE and Wavegen representatives, the site was labeled as the “gateway” to the largest wave energy resource in Europe. At the time of the slideshow, the project was expected to be consented to by 2007, designed from 2007-2009, constructed from 2009-2010, and commissioned in 2010. By building a 4 MW breakwater device on the northwest coast of the Isle of Lewis, the area could make a statement. The leading development would assume a “high profile” by being the first truly commercial deployment of wave energy devices.

The plan was for Wavegen and RWE to join the Siadar Pier Group in a rebuilding project that accomplished multiple uses. The local group wanted to rebuild a slipway in order to provide a safe place for boats to winter. The 240-meter breakwater would give the northwest Lewis community’s boats seasonal protection all while making energy in the 7 meter depth.¹⁰⁰ The energy companies would get a chance to deploy their breakwater technology. The nearby communities could benefit from the estimated £14m - £18m project in the construction phase and perhaps by an uptick in tourism to the locale. For years to come, an estimated 1,500 homes could have their electricity needs met by the wave devices.¹⁰¹ Wave energy for the Western Isles seemed to be rising.

The Siadar project had the potential to accelerate technological development for wave energy. Wavegen chief executive Matthew Seed noted that the

⁹⁹ Backwell, http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

¹⁰⁰ Backwell, http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

¹⁰¹ Siadar Energy Project, Isle of Lewis BWEA29 Glasgow. Published October 11, 2007. <http://www.taplondon.co.uk/bwea/lomond/thu/lomond%20Langley%20and%20Langston.pdf>

commercial 4 MW project extends the reliability insights gained from Wavegen's Limpet project on Islay to a focus on device efficiency and cost. Like the Limpet, the wave device used oscillating water column technology which kept the turbines dry. As waves pounded the breakwater, air travels in and out of concrete chambers, turning the blades. While this technology could be replicated in several locations, the real attraction was to move the wave devices from the breakwaters to locations offshore. Siadar project manager Bill Langley said "You could probably get up to 100 MW out of projects like this, but the exciting thing is that it is a stepping stone to the offshore resource."

Seed suggested that the Siadar project would allow the Wavegen's breakwater technology to "be employed at full commercial scale, paving the way for real cost efficiencies" which will accelerate wave energy's approach to other energy sources' prices.¹⁰² Wave energy technology needed greater cost efficiencies. The Siadar project was classified under the Renewable Obligation Certificates (ROC) directive. The 2002 law tried to incentivize energy companies to produce renewable energy in line with Scottish goals through type-specific subsidies organized by banding. Established technologies receive fewer bands. Tidal and wave energy carried high band values, 3 ROCs/MWh and 5 ROCs/MWh, respectively.¹⁰³ Still, for the immature technology, the funding proved inadequate to spur significant deployment.

In a moment viewed by some as another telling signal of interest in marine energy shifting towards tidal power, RWE Npower Renewables left its Siadar

¹⁰² Backwell, http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

¹⁰³ Backwell, http://www.rechargenews.com/news/wave_tidal_hydro/article1283979.ece.

partnership with Voith Hydro and Wavegen. Instead the company decided to focus on another joint venture with Voith Hydro, a 1 MW tidal energy test device deployed at EMEC in Orkney. The move occurred even after the Siadar project accepted £6 million from the Scottish government in 2010. The shift in focus was disappointing as breakwater technology had just had an overdue breakthrough. A month before the announcement, Wavegen finally commissioned the 300 MW Mutriku breakwater array in Spain after years of delay.¹⁰⁴

Unfortunately, the first Siadar project failed to materialize for the Outer Hebrides. The project was cancelled in 2011. Although the endeavor received official consent, the project suffered from delays, low funding, technology immaturity, and a lack of interest from the large parent corporations. Yet the ultimate culprit for the Outer Hebrides, evidently, was a lack of grid capacity.

Still, the Outer Hebrides is bursting with potential renewable energy developments. Observers in the Western Isles are looking for the expanding wind power industry to drive forward the investment for an expanded grid. Lewis Wind Power is planning a 130 MW wind farm in Stornoway and submitted a grid application. The 36-turbine wind farm received consent from the Scottish government in September 2012. The GDF Suez backed Bienn Mhor project is intending to build a 133 MW wind farm in the Outer Hebrides. Finally, Aquamarine wave energy is planning a 40 MW Oyster array off Lewis. With the grid and a robust wind industry

¹⁰⁴ Stromsta, Karl-Erik. "RWE Quits 4MW Scotland Wave Project to Focus on Tidal Power," *Recharge*. Published July 27, 2011. Last accessed May 27, 2014. http://www.rechargenews.com/news/wave_tidal_hydro/article1292487.ece

in place, the Western Isles can hope for “technology pull-through” to speed up the development of tidal and wave energy, as well as hydrogen.¹⁰⁵

Developments like these are vying for space on a 450 MW interconnector -- that has yet to be built. Scottish and Southern Energy (SSE)’s subsidiary Scottish Hydro Electric Transmission (SHE-T) has proposed building a subsea high-voltage cable to the Isle of Lewis but has consistently postponed construction due to rising cost estimates. The proposed 450 MW HVDC Link would be constructed between Grabhir on the Isle of Lewis and Beaully on the mainland.¹⁰⁶ Early optimism may have betrayed the interconnector effort. Originally the project was estimated to cost £400 million, but this “wildly unrealistic” estimate was revised to be at least a £700 million undertaking. The hesitation to build the interconnector has renewable energy companies wavering, nervous that their project may have no route for which to sell the produced electricity. On the other hand, SHE-T seems to doubt the projects will be built at all due to the difficult investment case. Also, SSE believes that high transmission charges should be required to pay for the pricy expansion. The expected high cost would reduce the ability of renewable company to produce profitable electricity. Thus, marine energy is at somewhat of a standstill in the Outer Hebrides, to the chagrin of the locals and developers, alike.¹⁰⁷

¹⁰⁵ *Renewable Energy & Western Isles: Creating a Sustainable Local Industry in the National Interest*. 2008 pg. 3.

¹⁰⁶ Monroe, Martin. “SSE Says Link to Scottish Island Would Cost More than \$1bn,” *Recharge*. Published November 5, 2012. Last accessed May 27, 2014. <http://www.rechargenews.com/wind/article1298766.ece>

¹⁰⁷ Stromsta, Karl-Erik. “Lewis Wind Seeks Grid Link,” *Recharge*. Published May 17, 2013. Last accessed May 27, 2014. http://www.rechargenews.com/wind/europe_africa/article1327014.ece.

The vacillating interest in breakwater wave development did not deter every company from the favorable Siadar site. The Npower withdrawal opened up room for another wave energy developer. In May 2013, Aquamarine Power, designer of the Oyster device, obtained full permission to develop a 40 MW wave energy array off northwest Lewis. Aquamarine's subsidiary, Lewis Wave Power Ltd., will lead the project. Between 40 to 50 of the second generation Oyster 800 devices will be deployed by the coast of Lag na Greine, close to Fivepenny Borne, at one of Europe's premier wave sites.¹⁰⁸ The Siadar 2 project will proceed in two stages. The first demonstration 10 MW array will be located between Siadar and Fivepenny at the Galston site. The following 30 MW lease will be located between Bàgh Dhail Beag and Tràigh Shanndaigh. For the non-Gaelic speakers, the site will be called simply the North West Lewis site.¹⁰⁹

Why is there this abiding interest in this northwest coast of Lewis location? Aquamarine selected the site near Siadar as both "representative" of Lewis and the "most appropriate" location.¹¹⁰ In essence, the place is the natural location for first deployment. The site has a strong wave resource, limited ecological sensitivity, an onshore site within an already developed area, and low potential conflict with local

¹⁰⁸ "Aquamarine Power Secures 40MW Lewis Seabed Leases," *Aquamarine Power*. Published May 22, 2013. Last accessed May 27, 2014. <http://www.aquamarinepower.com/news/aquamarine-power-secures-full-consent-for-40mw-lewis-wave-energy-farm/>

¹⁰⁹ "Aquamarine Power Secures 40MW Lewis Seabed Leases," *Aquamarine Power*. Published May 19, 2011. Last accessed May 27, 2014. <http://www.aquamarinepower.com/news/aquamarine-power-secures-40mw-lewis-seabed-leases/>.

¹¹⁰ "40MW Oyster Wave Array North West Coast, Isle of Lewis Environmental Statement: Volume 1: Non-Technical Summary," *Lewis Wave Power Limited*. Published March 2012. Last accessed May 27, 2014. <http://www.aquamarinepower.com/sites/resources/Reports/3174/Lewis%20Wave%20Power%2040MW%20Oyster%20Wave%20Array%20Non%20Technical%20Summary%20in%20English.pdf>.

fisheries and recreation. At an early entry location, Aquamarine chose a site offering low resistance to deployment. The careful selection, made possible by the early stage of the industry, helped the company gain the necessary environmental approval for it to test profitably the critical first full array developmental stage.

The ensuing summary shows how Siadar 2 is simply an ideal location for deploying marine energy devices. By following the results of the Lewis Wave Array's environment statement, the paper will outline the typical procedure and emerging concerns for consenting to marine energy projects.

First, the statement examines the array's impact to the non-human ecology. The report considered the coastal processes. About 20 kilometers north lies a Geological Conservation Review site due to noteworthy rock formations. Yet the wave farm will not impact the rocks physically or compromise the viewpoint. The report examined soils and hydrology within the sensitive peat environment within 1 kilometer of the site. The only impact envisioned relates to building the power station and improving the access road's drainage. The assessment used video surveys of the benthic environment. The videos determined the site was dominated by kelp with no critical conservation species identified.

The survey also examined the more visible species to be affected. The site is home to numerous fish and shellfish, but the report did not find that the area was crucial for spawning or nursery grounds. As far as ornithology, the survey found that the importance of the area during the breeding season was low. Important species such as the great northern diver, the eider, and the red-throated diver were identified

during the non-breeding season, but in numbers less than 1% of the Outer Hebridean population. Basically, most birds simply flew on past. On the other hand, the region is important for marine mammals. Cetaceans such as the grey seal, harbor seal, Russo's dolphin, common dolphin, minke whale, and harbor porpoise were identified. Though not seen in the assessment survey, basking sharks are also considered present. While the noise risks to cetaceans during exists, the Siadar site is viewed as small enough to cause minimal impacts. As far as the non-human ecology is considered, the statement finds that as long as construction and decommissioning takes place at times other than the peak breeding season, impacts will be small.

From the human perspective, the addition of the Lewis Wave Array to the other proposed renewable deployments will be significant through their aggregate impact. The Seascape Landscape and Visual Impact Assessment (SLVIA) determined that visually the development would have a "significant adverse cumulative effect."¹¹¹ Post-construction, the device will rise from 3 - 4.5 meters above average sea level, have a width of 26 - 33 meters, and have a breadth of 12.5 meters. Each device will be lit by night with consent to existing regulations. Lighting is also visually important, but the regulations are similar to other in-sea devices. Nevertheless, the protruding dimensions of the Oyster device are small considering the amount of MW produced per visual disturbance.

¹¹¹ "40MW Oyster Wave Array North West Coast, Isle of Lewis Environmental Statement: Volume 1: Non-Technical Summary," <http://www.aquamarinepower.com/sites/resources/Reports/3174/Lewis%20Wave%20Power%2040MW%20Oyster%20Wave%20Array%20Non%20Technical%20Summary%20in%20English.pdf>.

The socio-economic effect of the project has a few small negatives and, potentially, a large positive. For while the report found the boating use of the area was low, the high possibility of injury and expense of device damage from a wreck would be significant -- just as any collision with wave energy device would be. A total of four commercial shellfish and crab fishing crafts that use the site would be displaced. However, the report considers the site as not critical to the fishermen's entire livelihood. All the same, even this minimal impact ocean energy array presents a 'define the line' problem. If four displaced fishermen is acceptable, what about fourteen or twenty-four or a hundred and forty-four? Scotland and the rural communities need to decide which stakeholders will answer that question.

For the adjacent area community, the socio-economic benefit is predicted to be low. For the economically blighted areas of the Outer Hebrides, low is better than none. The Aquamarine array off Lewis would bring an estimated 98 - 200 jobs during construction, 37 long term operational jobs, and approximately £9 million in overall expenditures.¹¹² As such, many of the locals welcome the wave energy development. Chair of Urras Oighreachd Ghabhsainn (Galson Estate Trust), Angnes Rennie says the development is "very encouraging" and "the Urras and the community look forward to working with the company."¹¹³ The site's novelty could also be a noteworthy benefit for the area. The Siadar region has a minimal draw for tourists. The presence

¹¹² "Wave Energy Project Could Bring Hundreds of Jobs to the Western Isles," <http://www.aquamarinepower.com/news/wave-energy-project-could-bring-hundreds-of-jobs-to-the-western-isles/>.

¹¹³ "Aquamarine Power Secures Full Consent for 40MW Lewis Wave Energy Farm," <http://www.aquamarinepower.com/news/aquamarine-power-secures-full-consent-for-40mw-lewis-wave-energy-farm/>.

of a world leading renewable energy array will in all likelihood increase tourist interest in the site. All in all, the project's contribution to local, national, and international renewable energy ambitions exceed the possible detrimental impacts. Simply, Siadar 2 is a model development.

The planning, environmental and socio-economic scoping, and approval have all been achieved by the developer. Despite all the efforts, the same problem persists. If the site was built in a day, the Oysters would have no place to send their generated energy. The achievement of consent for the array led Aquamarine Power's Saltire Medal winning CEO McAdam to subtly place further pressure on the government to build adequate, visionary grid connection. He stated that the consent was "a significant milestone" for it signals the step to commercialization. McAdam continues "The goal of our industry is to become commercial, and to do this we need two things -- reliable technologies and a route to market. Our engineers are currently working hard on getting the technology right and we now have a site where we can install our first farm, with a larger-scale commercial build out in the years ahead." The unspoken reality is that Aquamarine is still missing the route to the mainland market.

Some observers are more overt. At the notice of the wave consent, Scottish Renewables' Niall Stuart directs his attention to both the grid absence problem and to the OFGEM strategy of island charging. The 40 MW consent was a great sign, but Stuart notes that "we can't forget that this is the kind of prize that could be lost unless costs for projects to connect to the grid on the island are set at a competitive level." By bringing up the U.K.'s standard system for electricity pricing, disparaged by the

stakeholders in the Scottish isles as island charging, Stuart reveals that even if the interconnector could be built by magic, the industry would still face financial hurdles.

Lastly, the leader of Comhairle nan Eilean Siar, the Outer Hebrides' island council, Angus Campbell directly addresses the need for the transmission link. After affirming wave energy's essential status to the global energy cause, he states "It is vital that developing technology like that of Aquamarine Power is retained in Scotland but, for that, we need to extend our electricity grid into the areas of best resource. Aquamarine's Power's announcement adds further weight to the call for our transmission owner, SSE, to move quickly on construction of this link for which there is so much consented demand."¹¹⁴

Will SSE listen? With pressure coming from the grassroots, industry, and government, I predict that the interconnector will be built eventually. The potential resource is too great to ignore. Now, whether the connection is constructed in time to reap the benefits of marine energy production jobs, I doubt this will occur. The Hebrides periphery location and lagging start in the industry, say compared to Orkney, suggest that the islands' economic hopes for marine energy should be realistically placed on gains from energy extraction only.

¹¹⁴ "Aquamarine Power Secures Full Consent for 40MW Lewis Wave Energy Farm," <http://www.aquamarinepower.com/news/aquamarine-power-secures-full-consent-for-40mw-lewis-wave-energy-farm/>.

CHAPTER 5: ORKNEY

Neil Kermode, managing director of EMEC, contends that Orkney is “the most exciting place to be living” with regards to renewable energy.¹¹⁵ Located in Stromness, the European Marine Energy Center (EMEC) is the world’s first grid-connected, full scale testing site. With this world leading center in place, Orkney has experienced considerable economic benefit from the emerging marine energy sector.

The Scottish government was determined to host a tidal and wave energy center. With great geography, some mainland electrical grid connection, and some base knowledge from Heriot Watt University’s International Center for Tidal Technology, Orkney was selected. In 2003, EMEC opened to the marine energy industry. Through the early research and development stage for marine energy prototypes, EMEC and Orkney have become essential knowledge bases for blue energy.

From the beginning, EMEC benefited from generous funding. The Highlands and Islands Enterprise led the push to establish Orkney for the world’s forefront testing center for marine energy, including efforts to raise money for the center. EMEC initially accepted £15 of funding from sources from the local island council, the Carbon Trust, the Scottish and U.K. government, and even the E.U.

The center succeeded and underwent a £5 million expansion in 2010. Now, EMEC has 5 wave testing sites and 7 tidal locations. The wave test site lies off the

¹¹⁵ “Neil Kermode, Managing Director, European Marine Energy Centre,” <http://www.saltireprize.com/sector/neil-kermode-managing-director-european-marine-energy-centre>.

southwestern coast of the Orkney mainland, while the tidal site is located in the 8 knot current off the island of Eday. EMEC also is developing 2 “nursery sites” for technologies smaller than the full-sized prototype.

The role EMEC plays in the industry is of high consequence. Test sites are essential for building confidence and know how for the emerging industry. Kermode states that EMEC is “home to the majority of the demonstrations underway around the world. We therefore act as the incubator space for machine developers, manufacturers and utility companies alike to learn how this industry is to be made to work.”¹¹⁶

For example, Aquamarine Power’s first full-sized Oyster turbine lasted through two harsh winter seasons off the Orkney mainland’s coast. Based on that success, the company deployed Oyster II at EMEC, the first of three next generation devices intended to be the first deployed wave power array. From the progress achieved at EMEC, the company received the first bank debt financing loan for a marine energy project. In September 2011, Aquamarine received a £3.4 million loan from Barclays. The funding gives Aquamarine the opportunity to finish deploying its 2.4 MW wave device array at the Billia Croo test site at EMEC in Orkney. Aquamarine had deployed its first 800kW Oyster device a month prior. The company plans to complete the three device array by 2013. Chief executive McAdam says “This deal is a major step forward for the marine energy sector. It shows Barclays has the confidence and flexibility to fund the right marine energy project - with a return

¹¹⁶ “Neil Kermode, Managing Director, European Marine Energy Centre,” <http://www.saltireprize.com/sector/neil-kermode-managing-director-european-marine-energy-centre>.

based on future energy production.” Furthermore, the loan “opens the door” for future wave projects. The loan relieved some observers who had seen wave energy fading in comparison to tidal energy.¹¹⁷ In anticipation of continued success, the company has worked to gain consent for a large 40 MW array off the Isle of Lewis. The Oyster is a perfect example of a trial at EMEC’s success, diffusion, and expansion.¹¹⁸

EMEC has already impacted the global marine energy sector. The first company to deploy a tidal device at the site, OpenHydro of Dublin, used its insights to commission a full-scale device in Nova Scotia’s Bay of Fundy, the strongest tidal race in the world.¹¹⁹ The site has attracted notice from Asia. EMEC’s director Richard Morris stated that “There are significant tidal resources across the globe and at EMEC we are very pleased to be exporting our knowledge and expertise to further the development of the global marine energy industry -- in this case strengthening ties between Scotland and China.”¹²⁰ The Ocean University of China in Shandong Province has asked EMEC to help advise the university to develop a Chinese marine energy testing center. First Minister Alex Salmond noted that the partnership will “help accelerate the development of marine energy technologies that will play an

¹¹⁷ “Barclays Makes Waves with £3.4m Loan to Aquamarine.” *BusinessGreen*. Published September 5, 2011. Last accessed May 27, 2014. <http://www.businessgreen.com/bg/news/2106554/barclays-makes-waves-gbp34m-loan-aquamarine>

¹¹⁸ “40MW Oyster Wave Array North West Coast, Isle of Lewis Environmental Statement: Volume 1: Non-Technical Summary,” <http://www.aquamarinepower.com/sites/resources/Reports/3174/Lewis%20Wave%20Power%2040MW%20Oyster%20Wave%20Array%20Non%20Technical%20Summary%20in%20English.pdf>.

¹¹⁹ “European Marine Energy Centre,” *Highlands and Islands Enterprise*. Last accessed May 27, 2014. <http://www.hie.co.U.K./about-hie/projects/archive/european-marine-energy-centre--emec.html>.

¹²⁰ “European Marine Energy Centre,” <http://www.hie.co.U.K./about-hie/projects/archive/european-marine-energy-centre--emec.html>

increasing role in powering the major economies of China, Europe and elsewhere, while reducing harmful emissions to tackle climate change.”¹²¹

Unlike the oil industry, or even wind, the marine energy does not now have an obligation to make a payment to the host community. While EMEC as a center is now self-sufficient from developer fees, the marine technology is still at the pre-commercial stage. Nevertheless, EMEC has made a large impact in the region. The leading center is credited by Elaine Hanton, the joint head of energy at HIE, for encouraging 600 supply chain companies to operate in the Highlands and Islands region. In its first decade, EMEC helped create 250 total marine energy jobs in Orkney, contributed £57 million GVA to Orkney, and furthermore £120 million in Scotland’s entirety.¹²²

Though still a pre-commercial technology, tidal energy has proven to bring positive impact to its site’s host. At the community level, the island of Eday has had the most net benefit from the center. Eday hosts the test births for the tidal energy devices. Representatives from HIE agree that EMEC has intentionally worked closely with the local community to provide some local benefit. Service provision has been the primary boon for the Eday.

Where does the Orkney marine sector grow from EMEC? Orkney’s small interconnector to the mainland is virtually full. Many Orcadian farms are large enough to host a wind turbine or two. Local landowners have been “very keen” to

¹²¹ “European Marine Energy Centre,” <http://www.hie.co.U.K./about-hie/projects/archive/european-marine-energy-centre--emec.html>

¹²² “European Marine Energy Centre” <http://www.hie.co.U.K./about-hie/projects/archive/european-marine-energy-centre--emec.html>.

capitalize on the fixed payments system for renewables. So in tandem with wind interests, Orkney joins every other island group in Scotland with the quest for greater grid connection. 2018 is the current date of hope for the Orcadian interconnector. Nearly everyone remotely involved with the marine energy in Orkney is lobbying for it.

If the grid connection comes, what will full deployment look like in Orkney? The renewable energy community may desperately desire the grid, but the population, according to some HIE representatives may not understand the magnitude of an industrial coastline. On the archipelago, talk about marine energy has circulated for years. Although there has been plenty of meetings and community sessions, the average citizen may be unaware of the total potential impact. For now, the marine energy devices remain a curiosity, a topic of conversation, in Orkney.

With regards to the impact of tidal and wave energy devices, the ocean energy sector does not know the full extent of the environmental ramifications of a fully commercialized industry. Predictive computer modeling can only account for so many variables. In the complex, fluid ocean environment, there is no substitution for real-life testing. At the same time, the actual risk of installing turbines is uncertain. A formidable knowledge gap exists with regards to the environmental effects. Although environmental impact assessments (EIA) have been made, only limited baseline data is present for the early generation devices. Therefore, the marine energy industry has resorted to a policy called ‘deploy and monitor.’ The strategy believes that careful observation of the effects that stem from the deployed prototypes will eliminate the

lack of environmental impact knowledge. Thus, the test centers in the Orcadian waters are closely watched. However, the full impact of an array will only be experienced when commercial deployment is reached. As epitomized by the deploy and monitor philosophy, the localized environmental concerns are poised to be reactionary. Only after damages have been incurred will there be sufficient evidence to recommend halting marine energy projects. The knowledge gap surrounding this emerging industry allows it to proceed quickly through the early stages with a level of environmental caution that either may or may not be ample enough to protect the sensitive ocean ecosystem. Environmental skeptics may wonder how much environmental harm is permissible before action is taken and whether the industry could survive a negative environmental performance. Orkney continues to serve as a crucial spot for this research.

CHAPTER 6: SHETLAND

Shetland's economy thrives off the offshore environment. Oil and gas with fisheries and aquaculture produce the vast majority of exports and provide over half of Shetland's private sector employment. While strong as a whole, the more remote islands, especially the ones the furthest to the north of Lerwick, are designated by the Highland and Islands Enterprise as Fragile Areas. As typical in remote Scotland, the archipelagos' population is steadily nearing the main city center. At least by the development agency, the island's future in oil and gas is through decommissioning project in the North Sea. Though difficult for islanders to realize, the days of the fossil fuel are numbered, despite the insistence in further offshore exploration. For the islands to continue to thrive off energy, Shetland needs to develop the renewable energy sector. The remote North Sea location which makes the renewable potential so high for wind, tidal, and wave, may also be the downfall for its renewables industry. To Scotland and the U.K., much less Europe, Shetland is peripheral.

While the majority of Shetland thrives, the more remote communities struggle to survive. The diffusion of renewable energy projects, which could both strengthen the Fragile Areas' economies and, perchance, dampen the wildlife and peaceful scenery tourism, needs three factors to develop. Shetland requires better inter-island transportation, strong connectivity, and export-conducive grid infrastructure.¹²³ One community, however, has not been daunted by the overall needs. The community on

¹²³ "Shetland - Key Sectors," *Highlands and Islands Enterprise*. Last accessed May 27, 2014. <http://www.hie.co.U.K./regional-information/area-information/shetland/key-sectors.html>.

Yell Island shows how far a determined group can take advantage of the emerging renewables sector.

Yell is a stark, harsh place. Samuel Hibbert described the island in his 1891 travel book of Shetland. He wrote “The northwestern extremity of this line of coast is remarkably bold, and at Gloup several naked skerries, the refuge of innumerable sea-birds, appear to have been torn from the neighbouring foreland, while their caves form the great resort of seals.”¹²⁴ In the century since, the environment still resembles his account’s portrayal.

Today, near the skerries, seagulls, and seals, an exceptional community revitalization effort is underway. The North Yell Development Council (NYDC) has recruited several community owned renewable energy projects to the remote island. The North Yell community includes residents of the hamlets of Cullivoe, Sellafirth, Gutcher, and Gloup.¹²⁵ The community may soon claim a laurel for renewable energy. Currently, the tidal and wave industry has no official process for community compensation. The absence of designated compensation did not squelch the island’s ambitions. North Yell, as the first community to potentially own a tidal turbine, may bring community ownership to the marine energy sector.

The Bluemull Sound races between Yell and Unst, the most northernly British isle. Along this tidal race, the world’s first community owned tidal power turbine will

¹²⁴ Hibbert, Samuel. *Descriptions of the Shetland Islands: Comprising an Account of Their Scenery, Antiquities, and Superstitions*. A. Constable and Company, 1822. http://books.google.com/books/about/A_Description_of_the_Shetland_Islands.html?id=OxMFAAAAYAAJ

¹²⁵ “New Project Manager for North Yell Development Council,” *Highlands and Islands Enterprise*. Published April 17, 2013. Last accessed May 27, 2014. <http://www.hie.co.U.K./about-hie/news-and-media/archive/new-project-manager-for-north-yell-development-council.html>.

be deployed. Nova Innovations and the NYDC have joined together to deploy a small tidal prototype for testing. Simon Forest of ScotsRenewables notes that the Bluemull Sound project will help to “regenerate the fragile economy of North Yell -- one of Europe’s most remote communities” while creating “a new model for tidal development where all the benefits go to the community through their ownership of the tidal power scheme.” Credit is due to Nova’s approach to holistic development. By offering “water to wire” service, the company helps facilitate community ownership by consolidating the process.¹²⁶

The island had to create the capacity to absorb the extra input. The 30 kW produced from the tidal device on the seabed 30 meters past the Ness of Cullivoe will enter the electricity grid at Cullivoe in Yell.¹²⁷ The community used a likewise ingenious technology to utilize the turbine’s electricity while benefiting the entire area. The narrow, fierce tidal race at Bluemull sound is a major shipping route. R.S. Henderson, primarily a transportation company, will be the main electricity consumer of the project. The firm operates an ice plant on the Cullivoe pier which sells ice directly to boats. The company refitted the ice-maker to be powered by the tidal technology. The ice patrons include the local fleet and boats from Orkney, Scotland, and Norway.¹²⁸ The boats require ice while harvesting from the area’s aquaculture and

¹²⁶ “World’s First Community Tidal Turbine for Shetland,” *Scotland’s Renewable Energy Guide*. Published September 5, 2011. Last accessed May 27, 2014. <http://www.scotsrenewables.com/blog/tidalpower/worlds-first-community-tidal-turbine-for-shetland/>.

¹²⁷ Robertson, John. “World First for Yell with Community-Owned Tidal Generator Poised to Go Live,” *The Shetland Times*. Published January 7, 2011. Last accessed May 27, 2014. <http://www.shetlandtimes.co.uk/2011/07/01/world-first-for-yell-with-community-owned-tidal-generator-poised-to-go-live>.

¹²⁸ Nisbet, Michael. “Services,” *R.S. Henderson*. Last accessed May 27, 2014. <http://www.rshenderson.com/services.php>.

fishing endeavors. Thus, the turbine aids the Yell community across sectors. When the ice-maker is not in operation, the electricity will enter the local grid.

The community took quite a risk to try to engage the tidal energy development. The North Yell community is willing to undergo the tidal trial. By purchasing a tidal device, the community is supporting an technology that brings no certainty of success like more established energy devices such as wind turbines. Retired pilot Andrew Nisbet, secretary of the NYDC explained to *The Shetland Times* “Obviously there is a degree of risk for us because tidal is experimental. It's not like buying a wind turbine that comes with a guarantee. But we're willing to give it a go and see how it pans out.”¹²⁹ The optimism and risk may pay off as marine energy technology matures and electrical capacity on Shetland expands in the future. The community hopes the successful trial will result in larger turbine deployment in the years to come, bringing even greater benefit to the area.

For now, the community turbine has been a process marked by delays. Simon Forest of Nova originally said that “Final commissioning is set for the end of 2011, making it the world's first community-owned tidal scheme.” Later, the NYDC director estimated a early spring 2012 beginning. Then the Bluemull project shifted

¹²⁹ Robertson, <http://www.shetlandtimes.co.uk/2011/07/01/world-first-for-yell-with-community-owned-tidal-generator-poised-to-go-live>.

its start date to Spring 2013.¹³⁰ The project is expected to start placing electricity into the National Grid by May 2015.¹³¹

Even with the setbacks, the Yell community has received some well deserved praise. The Highlands and Islands Enterprise applauded the community group for exhibiting “local leadership of an exceptional kind.”¹³² HIE Chairman Willy Roe stated that normal, even “understated” people formed the drive to take a world leading position on marine renewables. The efforts result in a “catalytic economic development” that should be profitable. Roe was “very struck by the integrated nature” of the Bluemull Sound project which tied together like a new fishing net so many stakeholders in the North Yell and surrounding areas.¹³³

The community driven project sells well politically. First Minister Alex Salmond noted that “the world's first community-owned turbine is to be manufactured and deployed on these shores is a truly fantastic endorsement of our burgeoning renewables sector.” The Bluemull project shows the potential for even small projects to have a national impact if the skill set, political commitment, and economic funding is present. Salmond emphasizes the geographic distribution of the renewable project “The turbine being developed by Nova Innovation -- based in Leith -- and

¹³⁰ “Siemens Developing World’s First Community Tidal Development,” *WaterBriefing*. Published December 5, 2012. Last accessed May 27, 2014. <http://www.waterbriefing.org/home/energy-and-carbon/item/6671-siemens-developing-world%E2%80%99s-first-community-tidal-development>.

¹³¹ “Island of Yell to House First Community-Owned Tidal Power Plant,” *OffshoreWIND.biz*. Published August 23, 2012. Last accessed May 27, 2014. <http://www.offshorewind.biz/2014/02/25/island-of-yell-to-house-first-community-owned-tidal-power-plant/>

¹³² Robertson, <http://www.shetlandtimes.co.uk/2011/07/01/world-first-for-yell-with-community-owned-tidal-generator-poised-to-go-live>.

¹³³ Robertson, <http://www.shetlandtimes.co.uk/2011/07/01/world-first-for-yell-with-community-owned-tidal-generator-poised-to-go-live>.

manufactured by Steel Engineering -- based in Renfrew -- will be used to power businesses in a Shetland community, showing the very tangible benefits that marine renewable power can bring to Scotland's businesses and people in the years to come."¹³⁴

The Bluemull Sound tidal development is a truly Scottish endeavor. Like a strong wave, the ripple effects from the community's determination to capture its tidal resource has spread throughout the nation. With assistance from Community Energy Scotland, the North Yell Development Council reached an agreement with the Nova Innovations to develop the world's first community owned tidal energy generation. The community collected the £168,000 necessary for the project through grants from Shetland Islands Council, Highlands and Islands Enterprise, and Community Energy Scotland. Based in Lanark, Scotland, Nova developed its turbine in tandem with Shetland Composites. Shetland Composites helped build in Lerwick one of the earliest prototypes of the Pelamis wave energy device in 2001.¹³⁵ For this project, Shetland Composites built the turbine blades.¹³⁶ The NAFC Marine Center in Scalloway, Shetland, is credited by Nova for significant support. Located in Renfrew,

¹³⁴ "Scottish First Minister Announces World's First Community-Owned Tidal Turbine," *OffshoreWIND.biz*. Published August 23, 2012. Last accessed May 27, 2014. <http://www.offshorewind.biz/2012/08/23/scottish-first-minister-announces-worlds-first-community-owned-tidal-turbine/>.

¹³⁵ Johnson, Peter. "World First with yell Tidal Generator," *The Shetland Times*. Published May 23, 2014. Last accessed May 27, 2014. <http://www.shetlandtimes.co.uk/2014/05/23/world-first-with-yell-tidal-generator/>.

¹³⁶ "World's First Community Tidal Turbine for Shetland," <http://www.scotsrenewables.com/blog/tidalpower/worlds-first-community-tidal-turbine-for-shetland/>.

Scotland, in the Leith region, Steel Engineering will team up with Nova for the construction of the Nova-30, a three-bladed rotor that will produce 30kW.¹³⁷

When companies like Nova make significant progress, large corporations take notice. Siemens has buttressed Nova's tidal generation research, including the Bluemull Sound project. The company is pleased to be involved with the first community owned tidal project. Simon Nadin of Siemens Mechanical Drives acknowledges that Siemens is "delighted [that] our drives and control units are being selected for such important projects."¹³⁸

Though small in voltage, projects like Bluemull have a significant impact on the renewables industry in Scotland. When First Minister Salmond announced the North Yell development project at Steel Engineering, he was present to open the Renewable Energy Skills Training Academy hosted by the company. Steel Engineering hopes to train 60 workers a year for renewable energy specialties within the academy.¹³⁹ Salmond praised the future-minded company. He stated that "Steel Engineering is a great example of a dynamic Scottish company leading the way in

¹³⁷ "Shetland Tidal Turbine Will Be 'World First'," *BBC News Scottish Business*. Published August 23, 2012. Last accessed May 27, 2014. <http://www.bbc.com/news/uk-scotland-scotland-business-19356794>.

¹³⁸ "Siemens Developing World's First Community Tidal Development," <http://www.waterbriefing.org/home/energy-and-carbon/item/6671-siemens-developing-world%E2%80%99s-first-community-tidal-development>.

¹³⁹ "Deal for Community Tidal Generator Powers Forward." *The Scotsman*. Published August 24, 2012. Last accessed May 27, 2014. <http://www.scotsman.com/news/scotland/top-stories/deal-for-community-tidal-generator-powers-forward-1-2486606>.

offshore engineering while ensuring that the next generation of engineers is ready and equipped to help take forward Scotland's renewables revolution."¹⁴⁰

Due to inclement winter weather, the Bluemull generator will have its final pieces bolted together in Shetland. The tidal device originally was planned to be shipped in whole to the island. Instead, Nova opted to ship the tidal generator in pieces by lorry. The siting of the final construction seems appropriate after the long wait for deployment of the world's first community owned tidal generator.¹⁴¹

If renewable energy is indeed the solution, Yell has decided to pursue an all options approach. In April 2011, the NYDC received consent for wind project over seven years in the making. The NYDC teamed with Community Energy Scotland for the five years prior to approval for the project.¹⁴² The North Yell community is also pursuing a potential 5 turbine, 4.25 MW wind farm near Gutcher. The relatively small scale project should be able to be developed easily even without construction of the mainland interconnector. However, for capacity to be available for wind energy, the grid at North Yells needs to be updated to a "smart grid" status with either substantial battery storage or a system that heats water for storage.

The estimated value of the 4.5 MW wind farm located between Basta Voe and Gloup is £1.3 million. Still, the NYDC will have to secure a £6 million loan to

¹⁴⁰ "Scottish First Minister Announces World's First Community-Owned Tidal Turbine," <http://www.offshorewind.biz/2012/08/23/scottish-first-minister-announces-worlds-first-community-owned-tidal-turbine/>.

¹⁴¹ Taylor, Ryan. "Yell Tidal Generator Parts Arrive," *The Shetland Times*. Published February 2, 2014. Last accessed May 27, 2014. <http://www.shetlandtimes.co.U.K./2014/02/21/yell-tidal-generator-parts-arrive/>.

¹⁴² Thomason, Louise. "Five-Turbine North Yell Windfarm Approved by Councillors," *The Shetland Times*. Published April 22, 2011. Last accessed May 27, 2014. <http://www.shetlandtimes.co.uk/2011/04/22/five-turbine-north-yell-windfarm-approved-by-councillors/>.

connect to the National Grid by May 2015 so selling electricity will be possible.¹⁴³

Eventually, the North Yell Development Council plans to expand the industrial estate at Cullivoe and develop a tidal array.¹⁴⁴

Projects the size of the testing device at Bluemull Sound can be absorbed or directed into the local grid, but electricity at the export scale requires a subsea cable. The massive and contentious Viking Energy onshore wind project offers the key to gaining the cabling connection.¹⁴⁵ Though the hundred-plus turbine array has polarized some interests in Shetland, most residents have accepted that the onshore wind resource in Shetland will inevitably be captured. Thus, the Viking project has gained considerable financing from local sources. The wind farm will impact the renewables sector beyond the onshore wind sector. By swinging the interconnector to Shetland, the huge Viking development could possibly allow the marine and wind resource to be developed to a greater extent because of a guaranteed market on the mainland. The scale of locally owned projects could then greatly increase. However, the grid connection will have to be constructed with enough room to add capacity. Until then, communities with a large endowment of renewables resource like North Yell are constrained by the grid capacity, not initiative.

Thus, a wind energy-driven bulk power initiative can help ‘scale up’ marine energy projects. Some companies are already moving in to seize the opportunity. For

¹⁴³ Taylor, <http://www.shetlandtimes.co.U.K./2014/02/21/yell-tidal-generator-parts-arrive/>.

¹⁴⁴ “New Project Manager for North Yell Development Council,” <http://www.hie.co.U.K./about-hie/news-and-media/archive/new-project-manager-for-north-yell-development-council.html>.

¹⁴⁵ Robertson, <http://www.shetlandtimes.co.uk/2011/07/01/world-first-for-yell-with-community-owned-tidal-generator-poised-to-go-live/>.

example, Vattenfall and Pelamis Wave Power formed a joint venture to develop Scotland's wave energy resources called Aegir Power. Named after a Norse sea god, Aegir looks to western Shetland for its first commercially deployed project.¹⁴⁶ The planned Aegir Wave Power Shetland 10 MW project plans to deploy 10 Pelamis machines off St. Ninian's Isle. The company has already secured a seabed lease with the Crown Estate. The project is set to be commissioned in 2018 because it awaits the interconnector to the Scottish mainland.¹⁴⁷ The project manager for Aegir's Shetland effort, Andrew Scott, said "The Shetland wave farm development is right at the forefront of this new industry, which has high future potential, and it's really exciting to developing this opportunity off Shetland."¹⁴⁸ If Shetlanders resemble the North Yell community, the Aegir development will be only the first of many new marine energy endeavors.

¹⁴⁶ "Aegir Wave Power: Shetland Wave Farm" *Aegir Wave Power*. Last accessed May 27, 2014. <http://www.aegirwave.com/>

¹⁴⁷ "The Shetland Project" *Aegir Wave Power*. Last accessed May 27, 2014. <http://www.aegirwave.com/the-shetland-project.aspx>.

¹⁴⁸ "About Aegir Wave Power," *Aegir Wave Power*. Last accessed May 27, 2014. <http://www.aegirwave.com/about-aegir-wave-power.aspx>.

CONCLUSION: TOWARDS A SCOTTISH MARINE ENERGY HUB

Originally, Scotland viewed its ample marine energy resource as a guarantee for economic gains. Since renewable energy is not depleted, the country could expect to eventually gain the benefits of development just by hosting the resource. While generating clean electricity is a positive, producing the entire marine renewable supply chain provides more extensive benefits for a long term duration. For this reason, Scotland has shifted its vision to be the global blue energy leader in a similar way to the Danish wind sector. The hub goal gives greater urgency to the sector than before since the total prize can be easily lost unlike the area's actual resource endowment. As such, the experiences of the four island regions previously discussed provide crucial insights for Scotland as the marine industry prepares to move forward.

Islay's experience with early wave energy devices suggests that initial sector leads are not secure. Without the marine energy center, the island lacked extensive research efforts needed to encourage expanded development. Scotland would do well to expand its commitment to ocean energy research. Also, Wavegen's experience with Voith reveals that even when large energy players enter the market, new technologies are not guaranteed funding or attention indefinitely. With a smaller percentage of total resources invested in a renewables project, a multi-national can more easily cut its losses and shift attention, as Voith did by moving from breakwater wave technology to tidal energy devices at Orkney. The Islay experience also serves as a reminder that

international companies can relocate away from Scotland, even taking the knowledge base away to its home country. Therefore, I argue that Scotland should employ some light version of protectionism, perhaps by bolstering access to financing for Scottish-based corporations. Foreign capital and interest should certainly be used to advance the sector. The quicker the industry develops, the better for Scotland. As long as barriers remain low, the area will likely be developed via Scotland. However, if progress is stalled, the international corporations could consolidate elsewhere with the national benefit occurring elsewhere. The Scottish marine energy resource itself is not enough to ensure the supply chain resides within the nation.

The Outer Hebrides experience with marine energy calls into question the strategy of restoring specific rural economies through electrical development. The starting point for a region is crucial to its development alongside an emerging industry. When left to market forces, developers seize the most advantageous situation. Since the marine resource is not exclusive to Innse Gall, the obstacles to Hebridean economic success -- peripherality, declining population, and poor infrastructure -- are magnified by the competition. Although the region has made many concessions to attract business development, the larger issues constrain significant progress. Therefore, I recommend that the Scottish Government quickly facilitate infrastructure and island pricing reform to stabilize the community in the Outer Hebrides. Without these macro-initiatives, the Hebrides will remain underdeveloped while other, more prepared regions consolidate their leads in the marine energy sector.

Orkney's success with the EMEC testing center reveals the immense advantage of research and development for the new industry. For one, the focus is placed squarely on the nation. The research advantage also proves conducive to obtaining ever-needed finance. Significantly for Scotland, the center is poised to begin exporting research across the globe which can prepare the way for eventually exporting the built technology. If EMEC can continue to provide leading information, Scotland can perhaps build a cachet within the marine energy sector. With its reputation and trust, Scotland could resemble for ocean energy what Switzerland symbolizes to watchmaking. Beyond the state of the industry, Orkney provides a great example of a diverse rural economy with access to high paying jobs. In tandem with other efforts, the renewables promise of remote community revitalization seems to be a serious possibility. At the same time, the limit for current development looms in the near future. The growing industry is looking for the next place to expand. For this reason, I recommend that the Scottish Government commission a nationwide marine spatial plan to streamline the path for the developers to extend their Orkney research into the commercialization stage in Scottish waters. If the transition from full-scale prototype to full-scale array occurs in Scotland, the sector lead may be captured for good. With full deployment in mind, Scotland should remember to consider the impact of the deploy and monitor strategy seen in Orkney and prepare robust mitigation strategies or employ development restraint in response to the incoming environmental data.

Shetland's Bluemull Sound experiment reveals that the grassroots level drive for marine renewables has been seriously underestimated. The community-driven strategy may be the best guarantee for achieving a lasting domestic industry. First of all, local stakeholders are the most loyal to the region. By involving the area's residents, opposition to development is discouraged and the demand for deployment is raised. Additionally, community-driven efforts rely on the local supply chain. Unlike multi-nationals, communities cannot call in private equipment and workers from another nation. Instead, communities use local knowledge, businesses, and government to facilitate development. The Bluemull Sound effort shows that even a very small-scale project can involve large areas of the nation. Even when the community engages an international development company, the corporation is tied to the area for the extent of the development. From these insights, I recommend that the Scottish Government initiates a plan that emphasizes future community ownership and benefit from the marine energy sector. The community potential should not be ignored just because the marine technology is currently pre-commercial.

Early on, the Scottish experts proposed that the nation's experience with offshore fossil fuel energy would provide key expertise which would accelerate the development of the marine renewables sector. Some technology transfer, primarily in saltwater resilient composites, has been applied to the emerging industry. Still, overall, the exchange between the offshore energy strategies has been very limited. At this stage, industry observers are not seeing a human capital transfer from the offshore oil and gas industry. Two conclusions can be drawn from this impasse. First,

the Scottish oil and gas is not yet in full decline. The industry continues to highly value its workforce. The efforts to expand in the harsher, further distant offshore oil fields has upheld the energy sector's employment at a consistent level. Secondly, the oil and gas companies have not recognized investing in the marine renewable industry as coinciding with their interest. The renewables industry is in competition with the fossil fuel energy sector.

The expected expertise transfer has instead occurred within the renewables industry, particularly between the wind and marine energy sectors. I contend in this paper that the renewables sector itself supports emerging forms green energy development. Governments can seem to support one renewable strategy to the apparent expense of the other less mature technologies. For example, some observers might argue that Scottish leadership prizes wind development over all other renewables. From this regional analysis, I have noted that the dominant renewable strategy, wind, has actually spurred on the development the marine renewables sector by primarily by creating significant infrastructure demand. Additionally, as seen with the West Islay Tidal project, companies with offshore wind experience are looking to employ their physical capital to other electricity projects in the marine environment. In the long run, the interplay between mature renewable industry and the emerging sectors could be even more beneficial to the Scottish economy than extensive grid infrastructure. As renewable energy gains momentum, Scotland's early lead in the marine sector, if carefully planned, could then foster other developing energy strategies for which Scotland has a viable resource such as biofuel or hydrogen.

For the immediate future, the marine renewables industry is signaling that the infrastructure is the primary barrier to development. In response, the companies are either pulling out of Scotland or proceeding as if the infrastructure will be in place. The lack of infrastructure is raising the risk profile of the fledgling industry. Importantly, the grid quandary is encouraging diffusion of marine energy expertise. Germany, Spain, Ireland, and the US, among others, are striving to develop their own industry. Infrastructure development takes time. Unlike finances or policy, the grid connection cannot be changed in a day. Therefore, the paper recommends the Scottish Government pressure, fund, and demand the necessary electrical infrastructure to be built in anticipation of an island-to-city energy system.

In order to ensure the expansion of a Scottish marine hub, the grid connection should be prioritized by the estimated speed of delivery for each marine strategy. If it is determined that interconnectors can be built most quickly to Orkney and Islay, the grid planners should consider what type of energy will be brought to maturity first. In this case, both areas would reinforce tidal energy development, while leaving wave energy devices behind. Therefore, the interconnector to the Outer Hebrides, though more time-consuming and costly, should receive higher priority than one of the tidal centers in order to ensure that the commercialization of the wave energy technology occurs in Scotland. Since the hub for onshore wind development is centered in mainland Europe, the interconnector to Shetland should receive the lowest priority as the area is a less efficient place to establish a renewable industry hub. Of course, the suggested order of planning is not intended to discourage expanding grid connection

to the islands. All four areas have proven to have the capacity and need for more electrical bandwidth.

To secure the potential global marine energy hub, Scotland needs to maximize its human potential. The value of human capital resource has been undervalued in the developing marine energy sector. Professor Ian Arbon, a chartered engineer and chartered environmentalist, makes the simple, salient point that training a civil engineer usually takes a decade. The observation underscores the decline in Scottish manufacturing, the number of Scottish engineering students, and the decline in STEM skills in education. In fact, despite the high need for these skill, Scottish universities have set a cap on the maximum number of students admitted into engineering programs.¹⁴⁹ Soon, Scotland will experience an acute skills shortage if the marine energy sector expands as planned. Thus Scotland should mobilize to train specialists for the marine energy sector. The major universities in Glasgow, Edinburgh, St. Andrews, and Aberdeen need to ramp up their marine energy programs. Collaboration with other U.K. universities is to be encouraged. As an emerging sector, tidal and wave energy need more than just engineers. Scotland does have highly skilled engineers, but so do other European countries. By developing a vibrant blue energy intellectual sector with environmental, legal, social science, and informatics expertise, Scotland can stave off the pressure from other nation's engineering skill sets. Additionally, Scotland should recruit outside talent. To do so, Scotland should

¹⁴⁹ Arbon, 9.

continue to view the marine sector as an international industry. Again, in all of this, speed is needed.

Of course, the estimated dates for renewables are not to be fully trusted. Whether from the technology immaturity, environmental concerns, inadequate funding, or lack of infrastructure, slowdowns from at least one of the four factors will arise in the process. While frustrating, the delays should not dishearten observers. If all factors were solved, Scotland's marine sector would be fully developed, not in the early stages of developing. However, the analysis does suggest that no matter how far along one of the sectors proves to be, a marine energy project can only go so far as the least advanced sphere. Instead of letting the delays mount, Scotland should compose a specialized marine energy task force for each of the four obstacles to provide consistent, updated recommendations to the Scottish Government.

Besides tackling barriers, Scotland should expand its green energy vision to further solidify its advantageous lead in the marine renewables sector. In *World on Edge*, Brown points out that wasted energy is massive strain on the earth. He writes "The opportunities to save energy are everywhere, permeating every corner of the economy, every facet of our lives, and every country. Exploiting this abundance of wasted energy will allow the world to actually reduce total energy use."¹⁵⁰ In addition to producing clean energy, Scotland should aim use lost energy. To this point, Scotland has relied on its natural resource endowment to direct its environmental program. If the nation remains focused solely on electric production, Scotland will be

¹⁵⁰ Brown, 115.

adhere closer to the Saudi Arabian template than to the diverse, expansive Silicon Valley model. Scotland should strive further deepen its knowledge base by pursuing energy efficient technologies. The production-only focus misses the possible reinforcing insights between the two environmental strategies. Just as the marine renewables sector has been historically neglected internationally, the field of energy efficiency is likewise ripe for expansion.

If a company is making electricity, the firm does not want demand for its product to fall. Scotland's renewables industry shows a clear discrepancy between production and consumption aspirations. The free market structure does not encourage demand decline. Though 'a MW saved is better than a MW made' is an industry truism, in practice, only at the household level is this followed. The initiative to reduce will not come from the marine energy developers. Without proper grid infrastructure, renewable energy companies covet local demand. Scotland wishes to encourage marine energy production, so the incentive for reducing energy is weakened by this infrastructure gap. The push needs to come from the public and the government players. Reducing electricity use is, unfortunately, not exactly required. For the U.K., the E.U.'s goal of reducing by 20% total energy used by 2020 is not a legal requirement. While the 20% renewable production is obligatory, the coinciding demand reduction is "merely an 'aspiration.'"¹⁵¹

By pursuing energy efficiency, electric demand could be substantially reduced. Scotland needs to realize that reducing electricity consumption will be

¹⁵¹ Arbon, 8.

lucrative. The less energy used at home, then the more renewable energy available to exported. While transmitting electricity over a long distance causes a significant amount of energy to be lost, a mature marine energy industry could overcome that through the benefit of its zero cost fuel input. Conversely, if Scotland reduced electricity consumed while equipping the transportation and heating sectors to absorb electricity, like the new electric train tracks, the industry could avoid this distance loss. The gospel of electrification should be applied to the population centers as well as to the rural renewable producing regions. Scotland should financially encourage an electricity efficiency industry to compliment the renewables industry. Rather than competing against each other, the two sectors would create such an energy knowledge base that they would support each other, double the reach of the Scottish expertise, and help ensure that Scotland became the ultimate host of the marine energy sector.

Finally, the Scottish marine industry needs to endure and press on. Adam Jarman, a technician for Pelamis Wave Power, has this to say. “Everything is difficult offshore. Strange unbelievable things happen at sea.” Still, Jarman believes the Scottish efforts will result in success. He says “Every year we get better and better at it and every year more and more people start to believe that it works.”¹⁵² If Scotland can avoid sector stasis, people will not need to have faith that the marine energy can work. They will just have to flip the light switch.

¹⁵² “Adam Jarman, Hydraulic Technician, Pelamis Wave Power,” *Saltire Prize*. Last accessed May 27, 2014. <http://www.saltireprize.com/sector/adam-jarman-hydraulic-technician-pelamis-wave-power>.

“The sea, the great unifier, is man’s only hope. Now, as never before, the old phrase has a literal meaning: we are all in the same boat.”

-Jacques Yves Cousteau-

“To stand at the edge of the sea, to sense the ebb and flow of the tides, to feel the breath of a mist moving over a great salt marsh, to watch the flight of shore birds that have swept up and down the surf lines of the continents for untold thousands of years, to see the running of the old eels and the young shad to the sea, is to have knowledge of things that are as nearly eternal as any earthly life can be.”

-Rachel Carson-